TOPOGRAPHIC MANUAL

O. W. SWAINSON

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DEPARTMENT OF COMMERCE

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U. S. COAST AND GEODETIC SURVEY
E. LESTER JONES, DIRECTOR

TOPOGRAPHIC MANUAL

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PREFACE

This manual is issued for the purpose of giving the general requirements of the United States Coast and Geodetic Survey for the execution of topographic surveys and to describe the instruments and methods used for topographic work. It is one of a series covering the various operations of the bureau. Two publications of the bureau, the Plane-Table Manual, Special Publication No. 85, and the section pertaining to topography of the General Instructions for Field Work, Special Publication No. 26, are superseded by this manual and will no longer be issued.

The topographic surveys carried on by the Coast and Geodetic Survey are usually for the purpose of compiling nautical charts and, in most cases, consist of a delineation of the shore line and of the territory immediately adjacent to the coast. This manual, therefore, deals chiefly with the methods used for this purpose and does not cover extensively the operations involved in the execution of inland topographic surveys.

Many helpful suggestions for the preparation of the manuscript were received from various members of the Coast and Geodetic Survey. Special credit is due W. E. Parker, chief, division of hydrography and topography, and E. H. Pagenhart, assistant chief of the same division, for their careful review of the manuscript and for their suggestions for its improvement.

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ILLUSTRATION

Department of Commerce,
United States Coast and Geodetic Survey,
Washington, September 30, 1928.

The general requirements for topographic work as published in part 1 of this manual supersede all previous instructions and circulars on the subjects treated. They shall be followed in the execution of all topographic work unless divergence therefrom is authorized in the special instructions issued for each project.

E. Lester Jones, *Director.*

TOPOGRAPHIC MANUAL

GENERAL STATEMENT

Topographic surveying is the process of determining the positions, on the earth's surface, of the natural and artificial features of a locality and of delineating them by means of conventional signs upon a plane surface called a *topographic map*. Such a map shows both the horizontal distances between the features and their elevations above a certain level called the *datum plane*. The representation of the variations in elevation is called the *relief*.

A topographic map is a representation in miniature of the area covered by it and the distance between any two points on the map, therefore, has a definite relation to the actual distance between the points. This relation or ratio is called the *scale*. The scale used for a topographic survey depends on the accuracy and amount of detail required.

Topographic surveys range, in accuracy and amount of detail shown, from a generalized sketch with very little control to a well-controlled cadastral survey in which even comparatively small details, such as fences, houses, etc., are drawn to scale. The character of the survey depends upon the purpose for which the map is to be used.

The production of maps for use in the compilation of nautical charts is a special branch of topographic work. In addition to skill in topographic surveying, it requires an understanding of the principles of chart construction and of the information regarding land areas that the mariner requires on his chart. A knowledge of hydrographic methods is necessary, for, with few exceptions, the topographic work of the Coast and Geodetic Survey is carried on in conjunction with hydrographic surveys. The economical prosecution of the latter often depends considerably on the intelligent cooperation of the topographer, especially in the establishment of control stations. Finally, proficiency in seamanship, with special reference to small-boat work, is essential, for the coastal topographer must be able to handle such boats and their equipment under all conditions.

For charting purposes the shore line must be shown as accurately as is required by the scale of the chart. Prominent hills and natural

and artificial features that may be used by the navigator must be clearly indicated in their true positions. Inconspicuous hills, ridges, ravines, and other similar features must be delineated with sufficient care to insure that they may be recognized beyond doubt. The amount of additional detail along and back of the shore line that should be mapped depends on the nature of the features and the importance of the locality. A profusion of unimportant detail is undesirable, as it may obscure more important features.

Part 1.—GENERAL REQUIREMENTS FOR TOPOGRAPHIC WORK

The general requirements for the topographic work of the Coast and Geodetic Survey, as prescribed by the director, are as follows:

1. Data to start survey.—Instructions for a topographic survey will be accompanied by such available information as is required by the character of the work. This will include geographic positions, descriptions of stations, and copies of previous surveys. The instructions and data must be examined immediately to make sure that they are clear and complete.

2. Arrangement of sheets.—A sheet plan should be laid out on a suitable chart or, in an uncharted region, on a reconnaissance sketch. In order to use as few sheets as practicable for the survey of any region, each sheet should cover as great a length of coast line as possible, while providing for necessary overlap with adjoining sheets and the inclusion, within the limits of the sheet, of all stations required for control. If practicable without sacrifice of these considerations, sheets should be laid out so that the projection lines are approximately parallel with the sides of the sheet. Sheets containing small detached areas of topography should be avoided, if practicable, by placing subplans on unused portions of sheets adjacent to such areas.

3. Identification of sheets.—Each topographic sheet used during a season shall be designated by a capital letter assigned in alphabetical order by the field party. The field letter of each sheet shall be clearly shown in one corner on the back of the sheet and shall be referred to in all correspondence, reports, etc., relating to the sheet until the latter has been registered and numbered in the office.

4. Paper for topographic sheets.—Whatman's hot-pressed, handmade antiquarian paper, size 31 by 53 inches, backed with cloth, shall be used for all sheets. This paper may be obtained from the office or a field station, upon requisition.

5. Care of sheet.—Care must be exercised to protect the sheet from injury and to keep it clean. When not on the table, the field sheet should be carried in a metal tube not less than 3½ inches in diameter. Tubes may be obtained from a field station or the office. Blank sheets should be stored flat.

6. Scales.—The scale or scales prescribed by the special instructions for a project shall be used except as provided in the remainder of this paragraph. In no case shall the scale of a topographic sheet be smaller than that on which the hydrographic work is done or the scale of the chart that will be compiled from the survey. A larger scale than specified may be used for any section of the work where such action appears to be warranted by local conditions, the particular purpose of the survey as stated in the instructions, or any other information in the possession of the chief of party.

7. Projections.—In order to eliminate errors due to distortion of projections constructed under different climatic conditions, projections shall be made, whenever possible, in the field. The construction of projections and plotting of

stations thereon shall be checked, and the initials of the persons performing and checking these operations shall be entered in ink in the lower right-hand corner of each sheet, together with the dates on which the work was done and the scale of the sheet.

These data shall be entered in the following form:

Scale--
Projection by-- (Initials, date)
Projection verified by------------------------------------ (Initials, date)
Triangulation stations plotted by---------------------------- (Initials, date)
Triangulation stations verified by---------------------------- (Initials, date)

To check for distortion at any time, a ½-meter distance shall be measured along the bottom of the sheet and another along the right-hand edge. Each of these two distances shall be indicated by two dots placed so that the testing length comes approximately along the middle of the edge.

8. Control of topography.—(*a*) The main control for all topographic work shall consist of stations at intervals of about 5 miles along the coast; such stations to be located by triangulation or traverse of at least third-order accuracy. To supplement the main control, additional stations shall be provided at intervals of about 2 miles along the coast; such stations to be located by theodolite cuts, transit and tape, or by plane-table graphic triangulation.

(*b*) Objects located by previous surveys but subject to change in position, such as flagstaffs, beacons, signal masts, etc., shall not be used for control until they have been relocated or their original positions verified.

(*c*) Triangulation and traverse executed by topographic parties for the purpose of establishing control stations shall conform with the instructions in the Manual of Second-Order Triangulation and Traverse. (See also par. 29.)

9. The control shall be established and the positions plotted on the field sheet before starting the topographic survey unless for some unusual reason it is impracticable to do so. Every effort should be made to establish the control first.

10. Where topography must unavoidably be carried on simultaneously with control surveys, and other work, the control, if practicable, shall be kept sufficiently in advance so that the distances (not necessarily the geographic positions) may be computed and plotted on the sheet before filling in the topography. In all cases where this will cause too great delay or is impracticable from other causes, the topographer shall check the distances on his sheet by the computed distances as soon as they are available, and where the discrepancies are larger than the allowable errors as prescribed in paragraph 12, he shall correct the error.

11. Topographic surveys in advance of control usually will be confined to surveys of moderate-sized bays. The preliminary control shall start from a base line, preferably measured with a steel tape. If this is impracticable, the base may be measured by a careful plane-table traverse run in both directions and without appreciable discrepancy in the two measures.

12. Standard of accuracy.—The standard of accuracy for all topographic work shall be based on the following considerations:

(*a*) All traverse lines run shall, if practicable, be checked by closing circuits or ending at a control station. On a 1:20,000 or smaller scale the closing error shall not exceed 8 meters per mile of traverse, and closing errors on larger scales shall be proportionately smaller (4 meters per mile on a 1:10,000 scale, etc.). Closing errors within these limits may be adjusted on the sheet. Larger errors shall be adjusted by a field examination. The provisions of this paragraph also

apply to the transfer and adjustment of topography executed at the same time or in advance of control surveys.

(*b*) Every part of the well-defined and permanent shore line and all other features determined shall be located with sufficient accuracy for hydrographic surveying and charting purposes.

13. Adjustment of instruments.—The plane-table alidade shall be carefully adjusted before use and at frequent intervals while in use. Telemeter rods shall be carefully tested before beginning a season's work, even though they were used with the same alidade and diaphragm during the previous season or have come direct from the office.

14. Telemeter rods shall not be read below a line of sight 3 feet above the ground for distances requiring one-half or less of the stadia-wire interval.

15. Repairs to instruments.—In general, instruments shall be returned to Washington for repairs, but, in an emergency, repairs may be secured in the field.

16. Features to be located.—Among the features to be included in coast topography are the following:

(*a*) The careful location of the mean high-water line (not considering storm-high water) and the low-water line so far as the latter can be determined or estimated without waiting for low tide. A special effort shall be made to locate the high-water line back of mangroves. (See p. 69.)

(*b*) Rivers and streams for a distance back from the coast, depending on their importance or in accordance with special instructions.

(*c*) Bridges crossing surveyed streams. Their character, width of span, width of draw (if a drawbridge), and clearance shall be stated. Information regarding clearance shall give the minimum headroom at the center of the channel span above (1) mean high water, where the plane of reference used on the chart is mean low water, or (2) mean higher high water, where the plane of reference is mean lower low water.

(*d*) Cities, towns, roads, railroads, important trails, transmission lines, and all distinctive topographic features within a reasonable distance of the coast. Wharves and buildings along the shore shall be accurately shown, but other individual buildings of a city or town shall not be shown unless they are of sufficient prominence to be useful as landmarks. In general, the inclusion of three streets back from the water will be sufficient for the chart. When there is no street system, the existence of a settlement shall be shown by the generalized symbol.

(*e*) Objects of a permanent recoverable nature, either natural or artificial, that may be identified for use in future surveying operations or as reference points for shore-line changes or aerial surveys. All objects referred to in this paragraph shall be located carefully, and the exact positions of some prominent feature of each shall be indicated distinctly on the sheet. The more important objects, and especially those landmarks which should appear on the chart, shall be named directly on the sheet itself, either close to the object or by reference letter and a note elsewhere on the sheet. Brief legends descriptive of important landmarks may also be placed on the sheet.

(*f*) Location and brief description of temporary signals established for hydrographic work.

(*g*) The nature of the coast line, of the area between high and low water lines, and of the general vegetation along the shore. These shall be shown by appropriate symbols or legends. It is very desirable that the upper tree line on mountains be shown whenever practicable.

(*h*) The location and elevation of hills or mountains within the limits of the sheet, other elevations, and contours or form lines.

(*i*) Off-lying features such as islets, reefs, rocks, sand bars, breakers, piles, fish traps, aids to navigation, etc. Such features shall be shown by appropriate symbols or legends. (See par. 38.) Elevations above mean high water of islets and conspicuous rocks should be stated.

17. **Magnetic meridian.**—The magnetic meridian shall be drawn at least once on each sheet by using the declinatoire while at a control station. In regions of possible local disturbance additional determinations of the magnetic meridian shall be shown. It shall be indicated by a line 6 inches long, having a plain arrowhead at the north end and no "feathers" at the south end, drawn not necessarily through the control point, but at any convenient point on the sheet. In all cases the date and the station at which the meridian was determined must be indicated, either by lettering along the line itself or by a note that clearly refers to the line. The declinatoire shall be checked at least once during the season at a station where the declination is known, and the error shall be indicated on the sheet. The declinatoire should be placed along the magnetic meridian frequently in order to determine if there is any local attraction.

18. **Elevations.**—The minimum number of elevations to be determined shall be that required to draw the contours or form lines with the required degree of accuracy. Every elevation determined shall be shown on the sheet.

19. **Plane of reference.**—The plane of reference for elevations shall be mean high water. Elevations shall be stated in feet. All elevations given, either by figures or contours, should represent the elevations of the ground. In wooded country where it is practicable to determine only the elevation of the tree tops an allowance should be made for the estimated height of the trees above the ground.

20. **Contours.**—Within the continental limits of the United States, exclusive of Alaska, the relief shall be indicated by contours. The term "contour" refers to a line of equal elevation based upon a sufficient number of elevations over the area so that no part of a contour, as shown in open country and on slopes of 5° or less, shall be out of position more than one-half the horizontal distance between the adjacent contours.

21. **Form lines.**—In Alaska and the Philippine Islands form lines approximating the accuracy of contours shall be used. For form lines the elevations of points, together with the elevations of prominent summits, shall be distributed over the area so that there will be at least one elevation for every 4 square inches of field sheet, with such additional elevations as can be obtained without unduly delaying the progress of the work.

22. Special care shall be given to form lines indicating the slopes and summits of points and headlands which may be of use in determining a vessel's position from seaward, as they are often used when the immediate shore line lies below the observer's horizon. Such form lines shall be verified, if practicable, by observations from the survey vessel at the distance offshore usually followed by coasting vessels.

23. **Contour and form-line intervals.**—For coast topography the contour interval shall be either 20, 50, or 100 feet, and the form-line interval shall be either 50 or 100 feet, as specified in the special instructions for the project. The choice of interval will depend on the nature of the country and the scale of the sheet. Only one specific interval shall be used on a sheet.

24. **Revision.**—In revision work the requirements for original topographic surveys shall be followed in so far as they apply to the project.

25. A bromide copy of the original topographic sheet will be furnished to the topographer. This is to be closely inspected, checked, and compared with the existing topography and the changes determined.

26. When certain features no longer exist, or when their positions as determined by the revision differ from those given on the original sheet, the facts must be thoroughly checked and this verification specially mentioned by appropriate notes either on the sheet or in the descriptive report.

27. Such features as may be shown on the original sheets but are not mentioned in paragraph 16 (such as inconspicuous buildings back from the water front, minor roads that do not lead up from the water, fences, etc.) shall be disregarded unless otherwise directed.

28. **Information from other sources.**—Both in original surveys and revision work the topographer shall, whenever possible, secure maps of towns and plans showing improvements, such as new terminals, bridges, etc. Such plans and maps must have sufficient points in common with the topographic sheet clearly marked on both to insure their location and orientation on the sheet. They shall be inspected in the field and clearly marked to distinguish between details that exist at the time of the survey and those that are projected only. Every blue print or plan submitted by a chief of party or other officer shall bear a statement over the signature of that officer as to the verification made in the field and the date. The purpose of this statement is to have the record show the extent to which the information contained can be relied upon to show conditions existing at that time. Such data shall be forwarded to the office with the topographic sheet. Details covered by properly inspected and controlled maps and plans shall not be shown on the sheet in the field. Data of this nature shall not, however, be used to obtain the positions of important objects which must be determined by the topographer.

29. **Marking topographic stations.**—A sufficient number of stations shall be marked to provide, in conjunction with the control stations, permanently marked stations at intervals of not over 2 miles along the shore line. Standard bronze hydrographic station marks shall be used for this purpose wherever practicable. Such stations shall be described on Form 524.

30. **Shore-line reference.**—Where a permanent mark is established or recovered along a shore subject to wave action and in such position as to make the measurements feasible, the field party shall measure the distance and azimuth from the mark to one or more points on the high-water line, top of beach slope, crest of bluff, or such other characteristic feature as, when compared with similar measurements to be made in the future, will best indicate the change in the shore line during the interim. On a straight or curving shore a single measure normal to the shore line will suffice. At points or headlands a larger number of measurements, preferably not less than three, shall be made in directions as widely separated as practicable. The resulting data shall be included in the description of station or recovery note in the same manner as reference marks and in addition thereto.

31. **Inking.**—Waterproof ink shall be used for all inking. Black ink is to be used except where otherwise specified.

32. Inking of sheets shall be done by the topographer or by a member of the party under his direction, and as soon as practicable after the field work is completed on a sheet. The inking of a sheet can not be considered as finished until all details specified in these requirements have been inked.

33. Accuracy, neatness, and clearness are necessary in inking a sheet; beyond this, fine drafting is not essential, and time should not be used in endeavoring to make a handsome drawing. The field topographic sheet is a survey record;

it should show all useful information plainly, neatly, and correctly. Valuable information, useful notes, etc., must not be omitted for fear of marring the appearance of the sheet; nor must the topographer hesitate to place the necessary information on the sheet because he is not an expert at lettering.

34. A note shall be placed at the bottom of the sheet giving the latitude and longitude, with seconds in meters, of one triangulation station that is plotted on the sheet.

35. Parallels and meridians shall be inked in fine full lines. The minutes of latitude and longitude of each parallel and meridian shall be numbered at each end with the degrees at the ends of those which are a multiple of five.

36. **Topographic feature symbols.**—The standard topographic symbols authorized by the Board of Surveys and Maps shall be used for all detail shown by symbols.

37. Great care must be taken not to confuse the symbol for sunken rocks (a simple cross), rocks awash (three lines crossing, one of which is parallel to the lines of latitude), and rocks above high water (heavy dot or shape). (See p. 68.)

38. Brief notes should be given on the sheet as to important reefs and rocks that show at various stages of the tide; as "bares so many feet at low water," "awash at low water," and the like. Such notes should agree with similar information in the hydrographic records. Terms such as "bare at high water" or "bare at ¼ tide" should not be used, as they are ambiguous.

39. The reef symbol shall be used only to represent the limit of reefs bare or awash at low water and should not be used to represent reefs covered to some depth at low tide. Limits of submerged reefs that are located by the topographic survey shall be indicated by a broken line inclosing sunken-rock symbols, or an appropriate legend. When a definitely located rock is shown by the rock-awash or sunken-rock symbol, it shall be encircled by a dotted line, such symbols without the circular dotted line being used to indicate generally foul ground and not the exact location of each rock indicated by the symbol. (See p. 68.)

40. Time need not be taken for the elaborate covering of a sheet with topographic vegetation symbols, but limits may be shown with words in the center to show the character of the area covered. The limiting lines shall be composed of the symbol representing the vegetation they inclose. Words may be used to indicate vegetation features for which there is no special symbol, and their limits indicated by a broken line. Descriptive words or legends of this kind must begin with lower-case letters to avoid confusion with geographic names and to meet the requirements of chart practice.

41. The limits of vegetation outside the high-water line, such as kelp, mangrove, etc., shall be indicated by symbol only.

42. **Station symbols.**—Except as provided below, triangulation stations shall be marked by small red triangles, with name of station (in full) and year of location in red. All signals and prominent objects located by topography which are to be used or are useful for hydrographic surveys, and permanent topographic stations, shall be marked by small red circles about 3 millimeters in diameter with name in red. *Exception:* In no case shall the above symbols be permitted to obscure an essential topographic feature; for instance, in case of an off-shore rock or islet used as a triangulation station the rock or islet shall not be obscured by the station symbol, but the latter may be omitted, if necessary, and the fact that a station exists at the point indicated by a name or legend, referenced to the point by an arrow.

43. The high-water line.—The high-water line shall be drawn with sufficient strength to make it clearly distinguishable. The identification of the high-water line on marsh is usually difficult. The outer edge of the typical marsh is vertical and is sometimes covered at high water, but for use on navigational charts this vertical edge should be indicated as the high-water line. The inner edge of the marsh (the limit of submergence at high water) when clearly defined may be drawn by a line distinctly lighter than the high-water line. Marshy formation outside the vertical edge of the marsh, especially when it is mud or grass of temporary growth, shall be shown by the mud symbol or the mud symbol with grass tufting but shall not be defined by a full line at the outer edge. The character of the marsh and the extent to which it is covered at high water shall be noted in the descriptive report.

44. Features not fully surveyed, such as the shore line back of mangroves, large areas of swamp land, or the extension of a stream beyond the limits actually run, shall be indicated by a broken line or appropriate legend.

45. Names and numbers.—With the exception of numbers on contours and names that should be lettered to conform with geographic features, all names, numbers, and symbols shall be lettered with their bases normal to the meridian and their tops toward the north. The numbers and names first mentioned shall be inked so as to be read when looking north. Names should, by their direction and proximity, clearly indicate the objects designated.

46. Names applying to land shall be in vertical letters, and names applying to water, including objects covered at high water, shall be in slanting letters.

47. All geographic names shall be in black ink, and names solely for surveying use shall be in red ink.

48. New names suggested by the topographer, unless in local use, shall not be inked on the sheet. If the locality of any suggested name can not be clearly defined in the descriptive report, the name may be placed in pencil within brackets on the sheet.

49. Contours and form lines shall be inked in red. Every fifth line shall be made heavier than the others. Numbers in red shall be placed on the accentuated lines with sufficient frequency, and on other lines when necessary, to make the contours or form lines easily interpreted. The numbers shall be placed on the axis of the lines to which they refer, breaking the lines sufficiently to receive the numbers, so as to be read when looking toward the north

50. Where contours or form lines back of hills and ridges are not located but it is desirable to indicate the formation, they may be dotted in red.

51. Elevations.—All elevations shall be inked in red. Except as specified below, the center of the number shall represent the point to which the elevation refers. If the number would obscure some topographic feature, it shall be placed adjacent to the point in parentheses. Care must be taken to avoid confusion. When a sharp summit may serve as a landmark, it shall be indicated by a dot with the elevation placed preferably to the right, or, if the feature has a name, under the name.

52. Magnetic meridian.—Magnetic meridians shall be inked in red, and the lettering pertaining thereto in red.

53. Revision surveys.—In inking revision surveys executed on bromide copies of the original sheet, red ink shall be used for all new and revised work, and blue ink for deleting.

54. For revision surveys on regular plane-table paper the instructions for inking an original sheet shall be complied with. The old work to which the new or revised work joins shall be put on the sheet but left in pencil.

55. Uninked sheet.—When for any reason an uninked sheet is transmitted to the office, the greatest care must be exercised by the chief of party that every feature, fact, and name is clearly and distinctly shown. It is particularly important in such case that small detached rocks along the shore, and other features that might be mistaken for accidental markings, should be made clear. Such objects should be inked by the topographer.

56. Titles shall not be inked on original sheets in the field but shall be furnished on Form 537a and forwarded with the sheet. The information must include general locality, special locality, names of chief of party and of officers makings surveys and inking sheet, date (month and year), scale, plane of reference, and contour or form-line interval.

57. Description of stations.—Descriptions of all permanently marked topographic stations and of all objects located in accordance with paragraph 16*e* shall be furnished on Form 524. This form shall be filled out as completely as possible, one card being used for each station or object. Seconds in meters must be carefully scaled and corrected for any distortion of the sheet. All stations located by triangulation must be described on Form 525.

58. Inspection and approval of sheets.—The chief of party shall inspect and approve each sheet before it is transmitted to the office or to another chief of party for completion. When circumstances are such that a departure from this rule is unavoidable or when any part of the provisions of the instructions for completing sheets are omitted, an explanation shall be forwarded promptly to the office. A full explanation of the circumstances must be given in the descriptive report accompanying each sheet.

59. Photographs or tracings of sheets.—When there is reason to believe that the method of forwarding a sheet is not safe, the sheet shall be photographed, or a tracing of the more important features of the original sheet made, and this record retained until the original has been received by the office. Otherwise, no tracing of an original sheet need be made in the field.

60. Landmarks for charts.—A list of the objects that are of sufficient prominence to use in water or air navigation, together with the positions and descriptions of same, must be furnished on Form 567 and mailed under separate cover. Form 567 shall be submitted in accordance with the 1934 memorandum entitled "Landmarks for Charts." The selection, determination, and description of these points is of primary importance.

61. Coast Pilot information.—All parties engaged in coastal topographic surveys shall collect Coast Pilot information and furnish notes covering the data obtained. For this work the instructions given in the Hydrographic Manual shall be followed as far as practicable. This information must be forwarded in a separate report.

62. Photographs.—Photographs should be taken of prominent landfalls, unusual topographic features, and interesting methods of surveying. The negatives, as well as prints, are to be forwarded if possible. They may be forwarded at any time. If prints only are sent with a season's or descriptive report, they shall be so arranged and marked or described on the back that they can be filed separately from the report. A statement must be made in the body of the report relative to the photographs.

63. A list shall be sent with the photographs, giving for each the point from which the photograph was taken, by whom taken, the date, a brief description, identification of prominent features shown, and if possible the bearing and distance from the point at which the photograph was taken to the subject. Glossy photographic paper should be used.

64. Geographic names.—Distinct names of points, islands, shoals, rocks, towns, mountains, etc., are necessary to the intelligent use of charts and Coast Pilots,

and the topographer must ascertain the accepted or native names and use such names in all possible cases. Attention must be called to all new names of geographic features—that is, names not previously used in the publications of the bureau—with a statement whether the name is in local use, and if not, what name is in use, with the reasons which prevented its adoption.

(*a*) The origin of each new name shall be stated. Geographic features must not be given the names of living persons, as the rules of the United States Geographic Board only permit the retention of such names in rare cases.

(*b*) All new names are submitted to the Geographic Board by the office before publication, and the decisions and rules of the board in regard to names are to be followed in all cases. In the Philippines the decisions of the Philippine Committee on Geographic Names govern in the same manner.

(*c*) Names already in use on charts and maps and in the Coast Pilots shall be verified; if well established and appropriate, they shall be adhered to, even though found to differ from the native or original name, especially if the feature is of more importance to navigation than it is to the inhabitants and if the native name is an awkward or difficult one.

(*d*) Dual names for the same object lead to confusion and inconvenience, and special care shall be taken to avoid giving a new name to an object already named, or changing a name already established. Where two names are in use, it must be ascertained which is the more appropriate and the more acceptable to the people of the locality, and report made giving the authorities.

(*e*) For such objects as require them, and for which acknowledged names can not be found, names shall be recommended, selecting as far as practicable designations that convey some idea of the form, character, productions, or traditions of the place, or some characteristic of its inhabitants; convenience of length of word and pronunciation shall also be considered. Common nouns or adjectives are to be avoided, as they probably have been applied to some other similar feature in the general locality. Report shall be made of names so recommended.

(*f*) Where the native names ascertained have not an established written form, they shall be spelled according to the system of the Geographic Board.

(*g*) In the Philippine Islands, in translating from Spanish into English nouns which are combined with geographic names, the following system shall be followed, except in specific instances where a different usage has already been established:

River, island, bay, point, and gulf are to follow the proper name.

Mount, port, and cape are to precede the proper name.

Rio Grande is to be translated simply river, unless these words form the specific name of a stream.

65. Descriptive reports.—A descriptive report entirely distinct from the season's report shall be submitted with each sheet. The descriptive report is for the purpose of supplementing original sheets by information not readily shown thereon, and which will be useful in the interpretation of the sheets, in the compilation of sailing directions, and in chart construction. Preference shall, however, be given to showing information on original sheets themselves when practicable to do so. It must be written concisely, omitting all unimportant detail, and shall be arranged in a systematic manner with each class of information in separate paragraphs under suitable underscored headings. The report must not be in the form of a letter, nor be a journal of the work. It need not contain anything about the movements of the party unless of especial interest or importance. Writing must not be nearer than 1 inch to the left edge of the paper. The heading shall be "Descriptive report to accompany sheet (insert

field letter and title of sheet)." The date of instructions under which the work was done must be stated.

66. Particular attention shall be given to the following subjects:

a. General description of the coast, following the geographic sequence of the published Coast Pilots or Sailing Directions, and including the aspect or appearance of the coast on making the land; describing prominent objects, as, on a bold coast, the headlands, peaks, etc., with their form, color, and height; or, on a flat coast, the spires, beacons, etc. Especially describe the landfall and objects useful as guides to navigation.

b. Landmarks.

c. Character of control used.

d. Closing errors of the traverses run and how adjusted.

e. Description of auxiliary surveying methods used; designating portions of sheet so surveyed, and indicating the manner of determining the locations of off-lying features.

f. Localities where form lines were verified by offshore observations.

g. In revision work, a clear explanation of any changes in prominent objects and off-lying features previously shown.

h. Describe any part of the work that is incomplete or unreliable or requires further examination, and the reason therefor.

i. Explain and give reason for methods or procedure deviating from standard practice.

j. Mention of any failure to join properly with former or adjacent work with recommendations for adjusting discrepancies.

k. List of new names—place names which have not hitherto appeared on the charts—shall be furnished under two heads: (1) Well-established local names; (2) names assigned by field officers. (See par. 64.)

l. List of plane-table positions. (See par. 67.)

m. Photographs that will illustrate the apparatus used or add to the knowledge of the locality, and a statement in the body of the report that such photographs have been obtained.

n. Changes of coast line shall be stated, giving reliable evidence as to recession, growth, subsidence, or emergence of shore line. If a resurvey, note any important facts regarding changes observed.

o. Character of marshes and the extent covered by high water.

67. **List of plane-table positions.**—The topographer shall make a list of the prominent objects on the sheets that have been determined by the plane table, namely, spires, chimneys, cupolas, flagstaffs, trees, etc., and such natural objects as sharp, well-defined mountain peaks, rock cliffs, and other objects that might be recovered and utilized, and particularly such objects as will be useful in hydographic work. The position of the particular point of each object observed upon shall be indicated by scaling the D.M. and D.P. from the sheet in the following form, giving the height, if available.

Plane-table Positions

Object and description	Latitude	D. M.	Longitude	D. P.	Height	Remarks
	° ′	*Meters*	° ′	*Meters*	*Feet*	
Cupola, Harrison's house	42 21	356	72 40	508	146	Top.
Cupola, Blackwell's barn	42 22	845	72 39	724	138	Weather vane.
Chimney, square house (Smith's).	42 25	632	72 37	395	157	Top.
North chimney, Rodger's house	42 26	981	72 38	1,023	125	Do.
Episcopal Church spire	42 25	63	72 40	875	250	Top of cross.
Murray Mountain	42 27	426	72 46	125	3,256	The north peak.

68. This list shall be attached to the descriptive report. The exact position of the objects referred to must be distinctly indicated on the sheet. Where space permits, the more important objects, and especially those landmarks which should appear on the chart, shall be named on the sheet either close to the object or by reference letter and note elsewhere on the sheet.

69. **Progress sketch.**—A progress sketch faithfully representing the extent of the entire season's work shall be prepared and forwarded at the end of each season. Each progress sketch must have a projection with latitude and longitude marked.

70. In order that the office progress charts may be kept closely corrected, a progress sketch, showing the topography accomplished, shall be forwarded to the office at the end of each month. The information thereon will be transferred to a progress chart and the sketch returned to the chief of party for use in making further reports. If not otherwise designated, the scale of the progress sketch shall correspond to that of the published chart showing the entire area outlined for the season's work.

71. Progress sketches shall be made on tracing vellum, using black ink only. They must not be of excessive dimensions, usually not over 18 by 24 inches. The scale of the sketch must be stated in the title. They shall be drawn sufficiently strong to be suitable for blue printing. The area surveyed shall be indicated by parallel ruled lines, not closely spaced.

72. In the Philippine Islands progress sketches of general coast work shall, if practicable and if they will come within the above dimensions, be on a scale of 1:100,000 (the scale of the Philippine coast charts). The stamped title form is to be used on such sketches, giving the following information: Class of work, island, locality, scale, dates, chief of party, vessel.

73. **Damage to property.**—Care must be exercised not to damage private property. When it is unavoidable, the instructions contained in the regulations shall be complied with.

74. **Relations with the public.**—The personnel shall at all times be courteous to the public. They should answer such questions and give information requested as does not conflict with the regulations.

75. Permission from the owner or person in charge must be obtained before entering private property, military reservations, and lighthouses.

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Part 2.—INSTRUMENTS AND EQUIPMENT

The plane table is one of the best instruments for topographic surveying, as with it the map is actually drawn in the field where and while the features can be seen and where the amount of detail to be mapped and the accuracy required can be judged to best advantage. The topographer, while in the locality, can compare his finished work with the topographic features as they actually appear and thus ascertain if his map represents them properly.

It is often impracticable, if not impossible, to measure with a tape or chain along the shore, and hence a stadia traverse is advantageous, as with it the observer can read the distance across indentations, past vertical cliffs dropping into deep water or breakers, or over a beach covered with large bowlders. To tape the distances would require much labor and many turning points of the instrument.

The plane table and the instruments used with it are described below. Auxiliary instruments that may be used to advantage in certain cases are mentioned in the section relating to field work.

Approximate weights of equipment.—Plane-table movement, 8½ pounds, boxed, 24½ pounds; plane-table board, 8¼ pounds, boxed, 26½ pounds; plane-table alidade, 7 pounds, boxed, 21¼ pounds; plane-table tripod legs, 11 pounds; 2 stadia rods, 16½ pounds.

PLANE TABLE

The plane table consists of a drawing board mounted on a tripod in such a manner that the board can be leveled and revolved about a central axis without disturbing the tripod.

Drawing board.—The drawing board used by the Coast and Geodetic Survey is a well-seasoned board 24 by 31 inches. It is 1 inch thick and has rounded edges. It is usually made of several pieces of white pine, tongued and grooved together with the grain running in different directions, to prevent warping. The lower side has three brass plates, in each of which is a threaded hole for receiving the screws that hold the board to the tripod head. These holes are approximately equidistant.

Tripod.—The tripod head, constructed so as to permit the movement of the board as mentioned above, is illustrated in Figure 1. The upper view shows the complete head; in the two lower views the upper movement has been removed and reversed to show the method of construction.

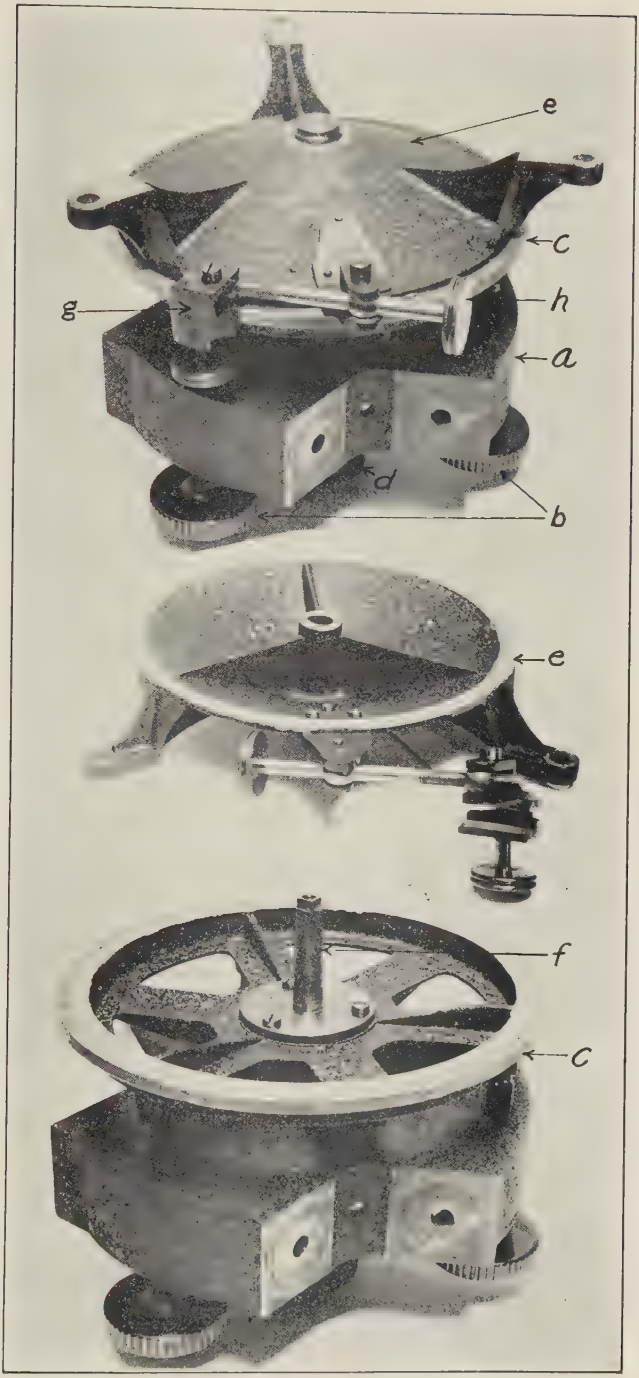

FIG. 1.—PLANE-TABLE TRIPOD HEAD

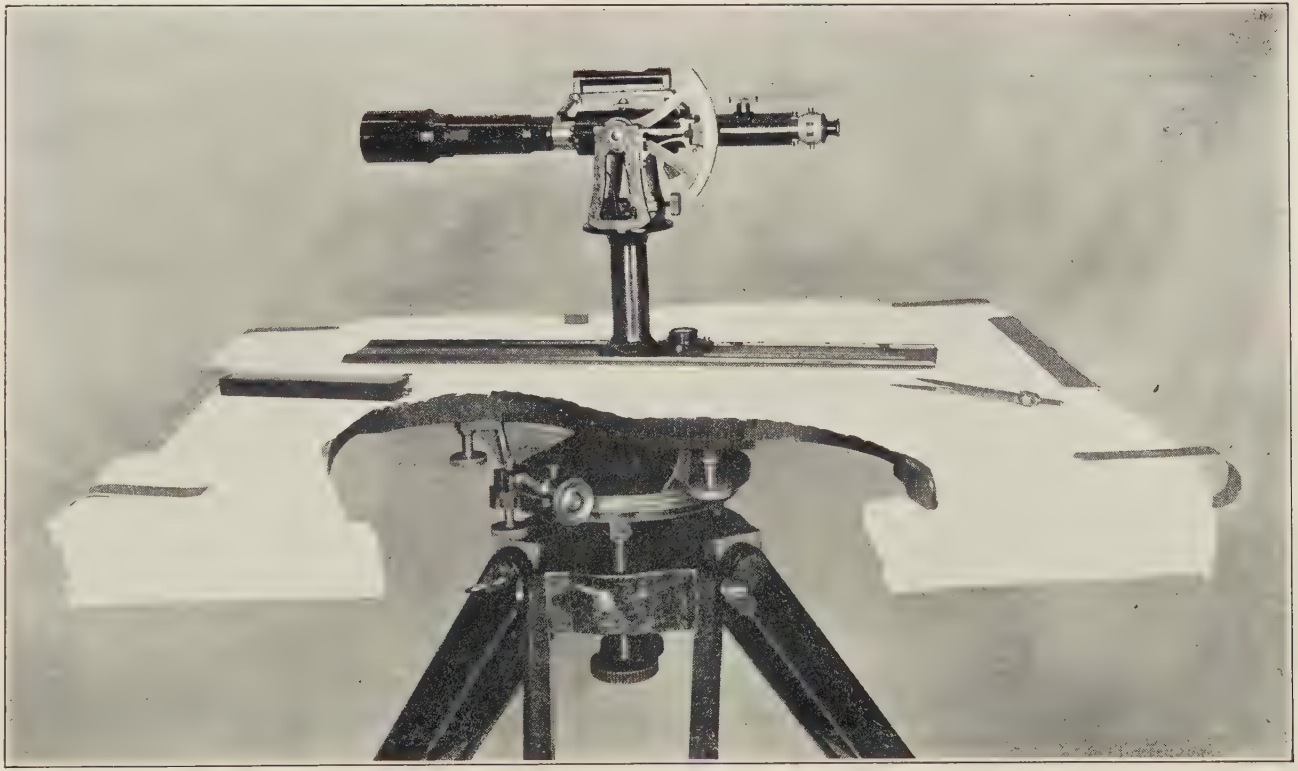

FIG. 2.—PLANE TABLE AND ALIDADE

The head is constructed of aluminum, with brass screws. The base (*a*) holds three leveling screws (*b*) and is shaped for attachment of the tripod legs. The plate (*c*) rests on the ends of the leveling screws and is secured to the base by a central bolt. A handwheel (*d*) screwing on the lower end of this bolt is loosened to level the board and is then set up to hold the plate firmly against the leveling screws. The upper motion (*e*), cone shaped and having three lugs for attachment of the drawing board, rests on the plate and revolves on the central shaft (*f*); it may be clamped to the plate by the clamp (*g*), after which it may be moved by means of the slow-motion screw (*h*).

The tripod legs are made of strong wood and are widely split and braced so as to hold the table firmly.

ALIDADE

The principal instrument used with the plane table is called an alidade. Its essential parts are a ruler upon which a telescope is mounted in such a manner that it may be raised and lowered while its line of collimation remains parallel to the edges of the ruler.

The type of alidade in general use consists of a skeleton metal rule, 21 inches long and 3½ inches wide, either nickel-plated or Bakelite enameled on the underside, from and perpendicular to which rises a metal column about 4 inches high. This column is surmounted by Y's that receive the transverse axis of the telescope. To one end of the axis is firmly attached an arc graduated 30° each side of a central 0°, the accompanying vernier being attached to the Y support. The arc moves with the telescope as the pointing is raised or depressed. A clamp and a tangent screw placed on the other side of the telescope, opposite the arc, control its vertical movement. A level is attached to the base.

The telescope is fitted accurately near its center of gravity within a closely fitting slightly conical bearing, to which is solidly attached the transverse axis. The telescope revolves within the cylinder through an angle of 180°, stops being fitted for that range. This affords an easy mode of adjusting the crosslines to the axis of revolution and for correcting with a striding level the errors of level and collimation and revolution of the telescope.

Upon the tube of the telescope are two shoulders on which rest a striding spirit level that can be readily reversed or removed. The eyepiece carries the usual reticule with screws for the collimation adjustment. To this is attached a glass diaphragm having one vertical and three horizontal lines extending across it. One of the horizontal lines crosses the middle of the diaphragm, the other two are placed equidistant from it, one above and one below. The upper and lower

spaces are each divided into halves by horizontal lines extending from one side to the middle. One of these spaces is again divided by a short horizontal line so that an intercept of one-half, one-fourth, or one-eighth of the space between the upper and lower lines may be obtained.

A plane table and alidade, with board and sheet cut away to show the tripod, are illustrated in Figure 2. An improved type of alidade with a side level attached to a movable vernier arm and an internally focusing telescope has been designed by the instrument division and will probably be adopted in the near future.

ADJUSTMENTS OF ALIDADE

From the nature of the service in some sections of the country the plane table is often necessarily subjected to rough usage, and there is a constant liability of a disturbance of the alidade adjustments. In careful hands, a well-made instrument may be used under very unfavorable conditions for a long time without being perceptibly affected, but adjustments at the beginning of field work and occasional examinations thereafter should always be made. If any difficulty be encountered while at work that can not otherwise be accounted for, it should lead directly to an examination of the adjustments.

The fiducial edge of the rule.—This should be a true straightedge. Place the rule upon a smooth surface and draw a line along the edge, marking also the lines at the ends of the rule. Reverse the rule and place the opposite ends upon the marked points and again draw the line. If the two lines coincide, no adjustment is necessary; if not, the edge must be made true or another instrument obtained.

There is one deviation from a straight line that, by a very rare possibility, the edge of the ruler might assume, and yet not be shown by the above test; it is when a part is convex and a part similarly situated at the other end is concave, in exactly the same degree and proportion. In this case, on reversal, a line drawn along the fiducial edge would be coincident with the other, though not a true right line; this can be tested by a true straightedge.

The level attached to the base.—Place the instrument in the middle of the table and bring the bubble to the center by means of the leveling screws of the table; draw lines along the fiducial edges and ends of the base upon the board to show its exact position; then reverse the alidade, placing the opposite edges and ends along the lines. If the bubble remains central, it is in adjustment; if not, correct one half by means of the leveling screws of the table and the other half by the adjusting screws attached to the level. This should be repeated until the bubble keeps its central posi-

tion whichever way the alidade may be placed upon the table. This presupposes the plane of the board to be true.

Great care should be exercised in manipulation, lest the table be disturbed.

Parallax.—Point the telescope to the sky, move the eyepiece until the cross hairs are perfectly distinct, and then direct the telescope to some distant well-defined object. If the contact remains perfect when the position of the eye is moved from side to side or up and down, there is no parallax, but if it does not, then the focus of the object glass must be changed until there is no displacement of the contact when the eye is moved. When this is the case, the cross hairs are in the common focus of the object and eyepiece. It may occur that the true focus of the cross hairs is not obtained at first, in which case a readjustment is necessary, in order to see both them and the object with equal distinctness and without parallax.

Vertical line of diaphragm or collimation.—Point the intersection of the vertical and the middle horizontal lines of the diaphragm on some well-defined distant object; revolve the telescope in its collar 180° and again observe the object. If the intersection covers it, the adjustment is perfect; if not, one-half the error must be corrected by moving the diaphragm by means of the adjusting screws and the other half with the tangent screw of the table. This operation should be repeated until the adjustment is perfect.

Middle horizontal line of diaphragm.—(1) Adjust the striding level by reversing it end for end and correcting its error—half the difference by its own adjustment, half by the tangent screw of the telescope.

(2) Point the telescope on a target and note the reading or make a mark where the wire points when the bubble is in the middle.

(3) Revolve the telescope in its collar 180° and note the reading or mark the place where the wire points when the bubble is in the middle.

(4) The mean of the two pointings is the true level line upon which the wire is to be adjusted. To make this adjustment, keep the bubble in the middle and by means of the adjusting screws bring the middle wire to bisect a point halfway between the two readings or marks. The adjustment may be verified by revolving the telescope as in (3), and if the middle wire again bisects the point, the adjustment is perfect.

Vernier.—To have the vernier read zero on the vertical arc when the middle horizontal line of telescope is level, adjust the striding level and the horizontal line of sight as noted above. Level the table with the level on the ruler; level the table more accurately in the direction of the line of sight by using the striding level; then, keeping the

bubble in the center, adjust the vernier to read zero by means of the two screws, working against each other, that hold it in place.

It is easy to have the adjustments accurate enough to serve for running curves of equal elevation, but in determining the heights of stations it is best to make the observations complete, with reversals, both of level and of telescope, taking the mean of the observations by which the errors of adjustment are eliminated. This, in fact, is always done with the theodolite and should be done with the alidade when precision is required.

The following will serve as an example:

Telescope direct

	°	′
Reading of vernier, level direct with bubble in center	+0	1
Reading of vernier, level reversed with bubble in center		0
Mean	+0	0.5
Station reading	+2	17
Angle of elevation (difference)	2	16.5

Telescope inverted

	°	′
Reading of vernier, level direct with bubble in center	−0	2
Reading of vernier, level reversed with bubble in center	−0	1
Mean	−0	1.5
Station	+2	12
Angle of elevation (difference)	+2	13.5
Mean	2	15

It will be seen, from analyzing these observations, that the level was one-half minute out of adjustment, the horizontal wire one and one-half minutes, and that revolving the telescope in its collar 180° changed its relation to the index on the vernier by 1′. The mean is free from all errors of adjustment.

TELEMETER ROD

The telemeter or stadia rod is used with the alidade for the measurement of distances. The rod used by the Coast and Geodetic Survey is simply a scale of equal parts painted upon a wooden rod. It is so graduated that each division corresponds to a given unit of distance. The number of divisions seen on it between two horizontal wires of the telescope, when the rod is held at right angles to the line of sight, is equal to the same number of the units of distance from the instrument to the rod.

The standard rod furnished by the office is illustrated at (*a*) in Figure 3. It is about 10 feet long, 3½ inches wide, and 1 inch thick.

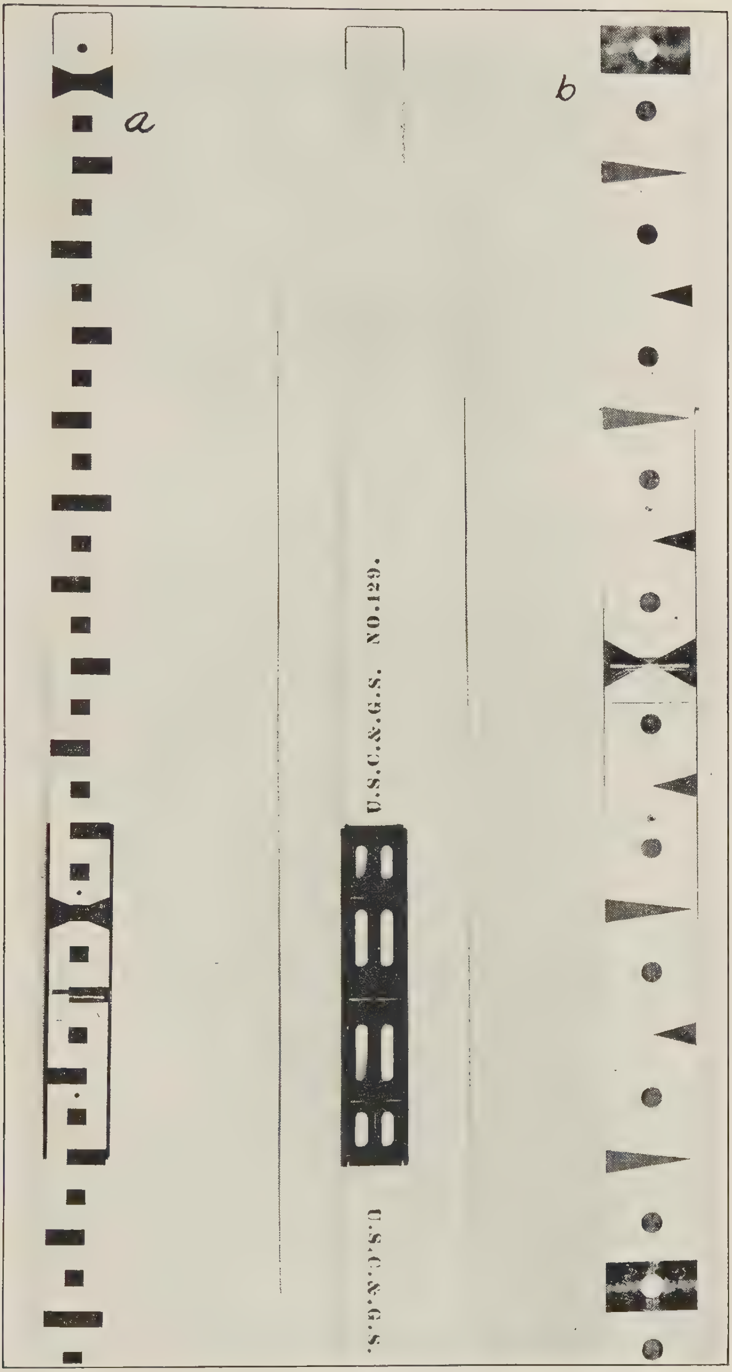

FIG. 3.—TELEMETER RODS

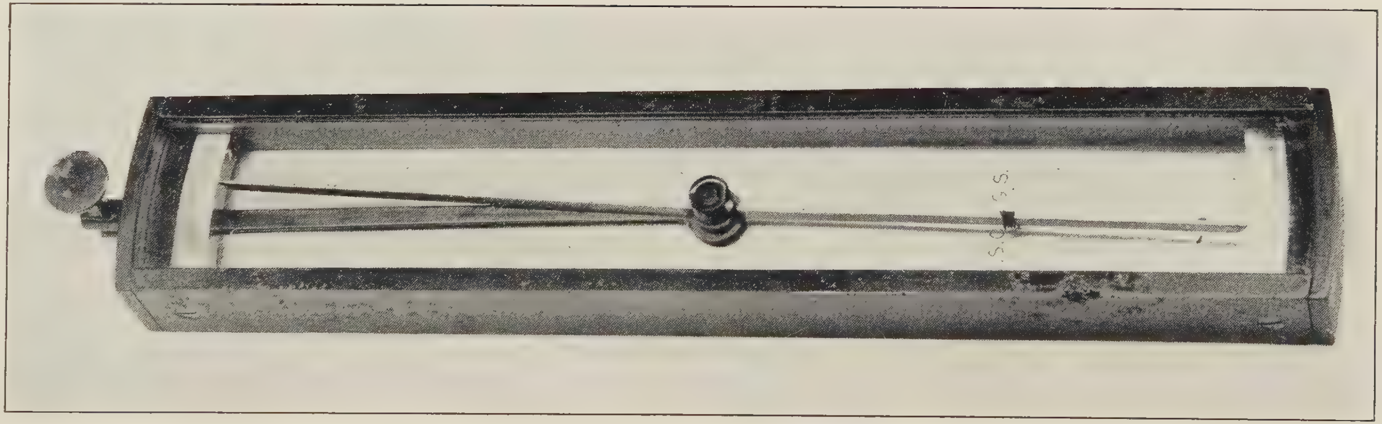

FIG. 4.—DECLINATOIRE OR BOX COMPASS

It is hinged in the middle and supported, when open, by an aluminum brace. The graduations are painted in black on a white background and are so spaced that the section between two principal marks (the combination of a rectangle and two triangles) appears between the two outside horizontal lines of the diaphragm at a distance of 100 meters.

In some cases, when rod readings at a considerable distance are necessary, it may be difficult to read this rod, and some topographers prefer a rod with more distinctive markings for special use in such cases. A rod that has been used with good results is illustrated at (*b*) in Figure 3. It can be prepared in the field and, under ordinary conditions, need not be hinged.

When a distance is so great that the intercept between the two outside lines of the diaphragm is greater than the length of the rod, a reading between two intermediate lines may be taken and multiplied by the proper number to obtain the distance.

In all cases the rod should be graduated for the particular instrument. In practice the alidade is mounted on a stand, and its center is plumbed over one end of a 100-meter base, measured on level ground. A line, representing the zero of the graduation, having been drawn about 5 inches from one end of the rod, the latter is held vertical at the other end of the base, zero mark upward. The observer at the alidade then makes the upper horizontal line of the diaphragm coincide with the zero mark and directs the rodman by signals where to draw a line that coincides with the lower horizontal line. This intercepted space on the rod then reads 100 meters and is subdivided to read meters, the graduation being continued to within a short distance of the bottom.

This graduation is represented by the equation—

$$d = \frac{f}{i} s + (f + c)$$

where d = the distance from the center of instrument to rod (in this case 100 meters);

f = the focal length of the telescope (which is 35^{cm} for the average alidade);

i = the distance between the upper and lower wires of the diaphragm (4^{mm});

s = the length of the intercepted portion of the rod ($1^{m}.185$);

c = the distance from object glass to center of instrument $\left(= \frac{f}{2}\right)$.

As indicated in the preceding equation, the readings of a rod graduated in this manner are not quite true for distances above or

below 100 meters. The vertices of the constant and similar angles (one subtending the chord represented by the intercepted space on the rod and the other the chord represented by the space between the upper and lower wires) do not lie at the center of the instrument, but at a distance beyond the object glass equal to the focal length of the telescope; and, therefore, the intercept on the rod will not be proportional for all distances from the center of the instrument.

To obviate this discrepancy, the instrument should be placed at a distance back from the end of the base equal to one and one-half times the focal length of the telescope $(f+c)$. To all readings of a rod graduated according to this last method the constant quantity $f+c$ must be added. This correction is small and may be ignored for mapping on a scale of 1:10,000 or smaller.

The formula for the correction to readings on a rod graduated by the first method is—

$$K=(c+f)\left(1-\frac{B}{B'}\right)$$

where K = correction in meters;
B = distance read on rod in meters;
B' = length of base, in meters, for which the rod was graduated.

The corrections for 50, 200, 300, and 400 meters are +0.262, −0.525, −1.050, and −1.575 meters, respectively.

DECLINATOIRE OR BOX COMPASS

This instrument, illustrated in Figure 4, accompanies the alidade, being carried in the same case. It consists of a rectangular box with a graduated arc at each end reading by half degrees to nearly 10° each side of zero. The magnetic needle is approximately 5 inches long and supported in the middle by its jeweled cup resting on a hardened steel pivot, from which it may be lifted, when not in use, by a lever. The long sides of the box are parallel to a line through the zeros of the arc.

HYPSOGRAPH

This instrument, illustrated in Figure 5, differs from the ordinary form of topographic slide rule used by engineers in three particulars: First, it is circular instead of rectilinear; second, it does not give elevations in the same unit as distances, but gives heights in feet when the distances are measured in meters; and, third, the arguments used for determining the heights are the horizontal distance and angle of elevation instead of the inclined distance and angle of elevation.

It will indicate the difference of elevation (uncorrected for curvature and refraction) for any distances and angles encountered in ordinary topographic work, with an error much smaller than the probable error of observation of the alidade.

The hypsograph is constructed of aluminum and consists of two concentric disks *CC* and *DD*, the inner one revolving about a spindle fixed in the center of the outer one. The outer disk *CC* has a logarithmic scale of numbers (circle No. 5) engraved on its beveled upper surface. Intermediate graduations, as well as the intermediate ones on the other scales to be described, are not shown in Figure 5.

The inner disk *DD* has four concentric logarithmic scales engraved upon its upper surface, representing the values of the quantities 3.2809 X tan n (3.2809 being the ratio of the meter to the foot, and n the vertical angle) for angles from 2′ up to 30°.

The inner one of the four (No. 1) is graduated for angles from 2′ to 10′, inclusive; the next (No. 2) from 11′ to 1° 44′, the next (No. 4) from 17° to 30°, and the outer circle (No. 3) from 1° 45′ to 16° 30′. They are placed in this order so as to bring the one most frequently used next to the number scale. To the left of the index line, on a part of the circle of scale No. 4, is another scale representing the logarithmic values of $\cos^2 n$ for reducing rod readings to horizontal distance when the rod is held above or below the plane of the observer's instrument.

Referring to Figure 5, *EE* is a milled head for revolving the inner disk; *F* is a reading arm, its fiducial edge serving as a guide line for reading the graduation marks on the outer circle (on *CC*) corresponding to a given angle on either of the inner circles; *G* is a screw that holds the two disks together; a spiral spring in the open space around the shank of this screw keeps the two disks in contact by its constant pressure. *K* is a clamping screw that works against a cylindrical lug *L*, which in turn presses against the circumference of the disk *DD* and holds it securely clamped. The lug is introduced between the screw and disk so that there may be no tendency to rotate the disk when the clamp screw is set.

Directions for use.—*To find the difference in height, corresponding to a given distance in meters and an angle of elevation or depression.*—(*a*) Unclamp the instrument by loosening the small brass screw.

(*b*) Turn the inner disk until the index line coincides with the given distance, in meters on the outermost circle.

(*c*) Clamp the instrument.

(*d*) Swing the reading arm around to the right, clockwise, till its fiducial edge coincides with the graduation mark of the given angle.

(*e*) On the outermost circle, at the fiducial edge of the reading arm, read the scale for the numbers composing the integer and decimal of the required difference of height in feet.

To locate the decimal point in the result.—On the reading arm will be seen the numbers −1, 0, −2, and −3. These numbers show how many figures of the scale reading are to be pointed off for the decimal.

Thus, if the index line be set at distance 300 and the given angle is 3°, the number —1 will be seen on the reading arm over the circle on which the 3° is located. This indicates that there will be one figure of the scale reading pointed off for the decimal. Hence the required difference of height is 51.6 feet.

Similarly, if the given distance is still 300 meters but the angle 30°, the required difference of height is 568 feet. The figure 0 on the

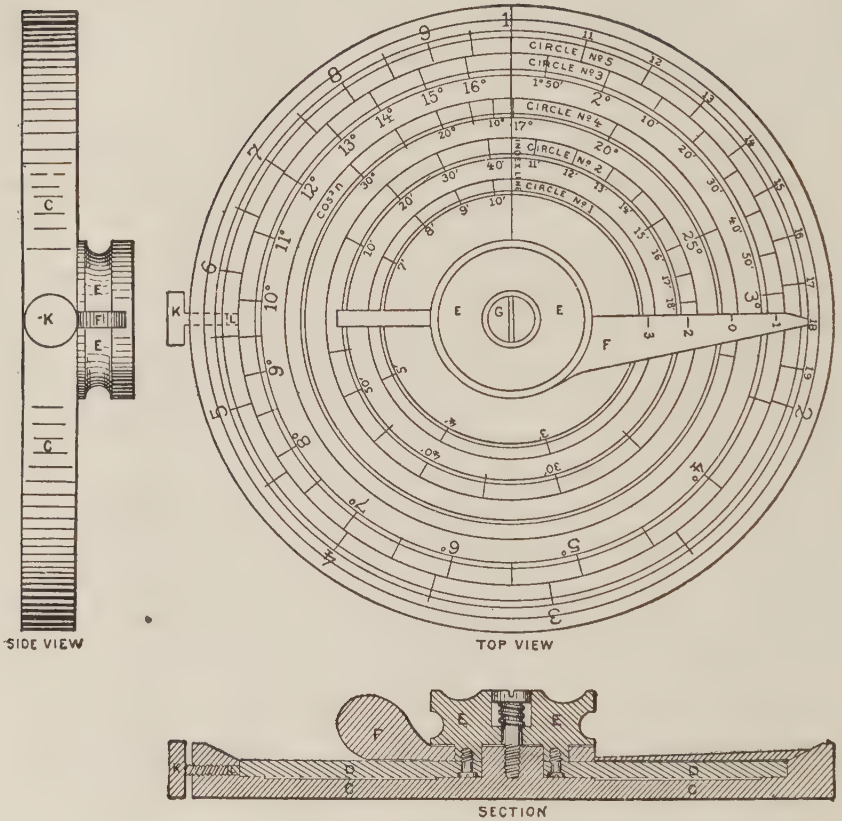

FIG. 5.—Hypsograph

reading arm, over the circle on which 30° is located, indicates that the whole number of figures of the scale reading is to be taken for the required difference of height.

In like manner, if the distance is still 300 meters but the angle 20′, the difference of height is 5.73 feet, and for 300 meters and 2′ it is 0.573 foot.

If, however, the reading arm, in swinging around to the right, clockwise, from the index line to the given angle, passes the starting point, 1, of the outermost scale, the numbers on the reading arm

must each be increased by unity, and instead of -1, 0, -2, and -3, they become 0, $+1$, -1, and -2, and the number of figures in the integer is increased accordingly.

Reduction of rod readings on inclined sights to horizontal plane of observer.—Set the index line on the graduation mark on the outermost scale corresponding to the reading of the inclined sight, and then swing the reading arm to the left, traversing the graduation on circle No. 4 marked "$\cos^2 n$," until its fiducial edge coincides with the given angle of inclination. Then, on the outermost circle, read the graduation under the edge of the reading arm for the required horizontal distance.

Thus, for an inclined distance of 300 meters and an angle of 20° the horizontal distance is 265 meters.

For distances greater than 1,000 meters a correction for curvature and refraction must be applied.

PLANE-TABLE SHEET

From the standpoint of accuracy the plane-table sheet is the least satisfactory item of the plane-table equipment. Owing to its hygrometric nature, it is very susceptible to atmospheric changes, expanding and contracting unceasingly. This would be an insignificant source of error or annoyance if it were equal in all directions. The map or plan would then simply change its scale, for which an allowance could readily be made. But the objectionable feature arises from the unequal expansion and contraction which changes the relative distance and directions of the points. It has been determined by experiment that strips cut longitudinally from drawing paper varied from 10 to 25 per cent more than strips cut transversely from the same paper.

Various substitutes have been tried, but none has proved entirely satisfactory. Two sheets of Paragon paper, mounted with the grain at right angles and with cloth between them, have been used; but, as it can not be rolled, the size of this sheet can not be larger than the board. For Coast and Geodetic Survey work a longer sheet is much more economical, because a smaller number of points are needed to keep the work within the control of the triangulation than will be required if the sheet is limited to the size of the table. A certain amount of overlapping work, of which there is more or less at the junction of the two sheets, also is avoided.

The plane-table sheet of the Coast and Geodetic Survey consists of a sheet of Whatman's hot-pressed, handmade antiquarian paper, 53 by 31 inches. It is backed with muslin, which extends about 1 inch beyond the edge of the paper to protect it from fraying.

Seasoning.—To reduce distortion to a minimum, the sheets should be thoroughly seasoned by exposing them alternately to a very damp

and a very dry atmosphere before the projections are constructed. Care must be exercised not to warp the surface by too severe a seasoning. On testing a sheet after a week of such exposure it will be found to have much less tendency to expand or contract unequally.

Celluloid sheets.—In localities of excessive rainfall, celluloid sheets are sometimes used to carry on work in light rains when it would be impracticable to use a paper sheet. Such a sheet should be about the size of the drawing board and should have one surface roughened to hold pencil marks. The topographic details drawn on this sheet should be transferred to the regular sheet at the end of each day.

Some European countries have used a paper made impervious to water by the application of a solution of celluloid.

The preparation and care of sheets are discussed in a later section of this volume.

LIST OF EQUIPMENT

A list of instruments and equipment usually required for topographic surveying operations is given below. Equipment required for transportation, camping, or medical use is not included, because it varies considerably, depending on the conditions under which the work is done.

1. Plane-table sheet on which the topography is to be delineated.
2. Plane-table tripod legs.
3. Plane-table head with screws to hold board.
4. Plane-table board.
5. Alidade.
6. Two stadia rods.
7. Clamps for holding the paper on the board; 2 long-side clamps, 4 medium-sized end clamps, and at least 6 small clamps.
8. Metal (usually galvanized iron) tube for carrying sheet.—This tube must have a diameter of at least 3½ inches, so that it will not be necessary to roll the sheet so tightly as to injure its surface. Tubes furnished by the bureau are 36 inches long and have a diameter of 4½ inches. The tube should have a close-fitting cap, and should be covered with canvas as an insulation against heat. It should be provided with a carrying strap with one end attached to the cap and passing through a loop near the cap so that it will tend to hold the cap in place.
9. One-quarter meter scale, with a 1:10,000 scale on one side and a 1:20,000 scale on the other.
10. Hypsograph.
11. Rubber sheet, about 30 by 36 inches.—This rubber should be white and of good quality. Rubber sheeting obtainable in drug stores is good. Short lengths of tape, one sewed to each corner, are convenient for securing the sheeting in place and preventing it from being lifted by the wind.
12. White cloth about 30 by 54 inches, to be kept rolled up with plane-table sheet to prevent back of sheet soiling its face and to cover the sheet while on the table and not being used.
13. Two small pieces of cloth, to be held under the hands while working on the sheet in hot weather.

14. One pair spring dividers (dividers with a slow-motion screw).
15. Pair of binoculars.
16. Large plane-table umbrella.
17. Emery-paper pad for sharpening pencils.
18. Two each 4H and 5H (or 6H) pencils.
19. Soft eraser.—" Ruby " 112 is excellent. Cut off a small piece to put over divider points.
20. A few yards of white cloth for marking " set-up " points.
21. Black and white flags with which to signal rodmen.
22. Thirty-meter steel tape.
23. Hammer, nails, station marks, and signal material if any signals are to be erected.
24. Small box or pocket holder for pencils, dividers, emery-paper pad, etc.
25. Knife for sharpening pencils.
26. Bolos or machetes for cutting brush.
27. Notebook, such as " sketchbook " which is furnished by the bureau in which to make notes for descriptive reports, etc.
28. Prismatic compass (only when necessary for an auxiliary survey).
29. Padded cover for tripod head.—At the close of the day's work a padded canvas cover should be put over the tripod head, which is not removed from the tripod legs. This is to protect the various screws and parts of the head from injury.
30. Canvas cover for plane-table board.—A canvas cover with shoulder carrying straps should be provided for the board. The board is carried separately from the tripod to and from work, especially if it is necessary to go through brush or wood. The board is too large to be carried under the arm and affords no grasp for the hand. The cover affords an easy method of carrying it on a person's back and also protects the face of the board from scratches and dents.
31. Small pencil compass for drawing circles around the positions of objects that are to be used for signals.—This will be found an aid to neatness and a help in retaining the exact point denoting a signal which is often lost or confused with the rough circles marking set-ups. An improvised compass may be made by driving a needle into the end of a round stick about the size of a pencil. Cut the stick off so that ¼ inch of the needle point projects beyond the end. Hollow out one side of the needle-point end of the stick and insert a piece of 4H lead, chisel pointed on one side, as in a pencil compass. Let the needle project slightly farther than the lead point. The deeper the hollow is made, the nearer the lead will be to the needle, and hence the smaller the circle that will be made. Wrap thread around the stick and lead to hold the lead in place.
32. Manual containing tables for correction of inclined sights, etc.

EMERGENCY REPAIRS

It is sometimes possible for the topographer to make temporary repairs to instruments broken in the field, so as to continue the survey until replacements can be secured. New instruments should be secured and the broken ones sent to the office of the bureau promptly. The Regulations of the Coast and Geodetic Survey give the conditions for having repairs made locally.

Broken cross hairs.—If the cross hairs or the diaphragm on which the cross-hair lines are etched become broken, and there is no spare

diaphragm on hand, secure a spider that will spin a fine web and cause it to drop off some object and suspend by its web. Open a pair of dividers about ¾ inch and wind the web onto them, keeping each strand separate. Open the dividers slightly, thus stretching the spider-web threads. The threads can now be laid across the cross-hair ring and fastened with shellac or with tree gum or flour-and-water paste, if no shellac is available, at the approximate correct distances apart. Replace the ring in the alidade and test the spacing of the spider webs by sighting on the stadia rod over a measured distance. Change the position of the threads, or put in new ones, in accordance with the required correction. The distance between them must be tested frequently thereafter, as they are very apt to become disarranged.

The installing of spider-web cross hairs, however, is very tedious and usually unsatisfactory. It should be resorted to only when absolutely necessary.

Bent rule of the alidade.—If the rule of the alidade becomes bent, it must be straightened with care. After straightening, check the edge by drawing a line on the sheet with it and then lay it along the line with the instrument reversed. Small dents can sometimes be removed by drawing the rule back and forth over the edge of a board.

Broken standard of the alidade.—The standard connecting the rule to the telescope, if broken, can sometimes be repaired by inserting a tightly fitting stick in the hollow arm and binding splints securely around the outside. It is not necessary to have the axis of collimation of the telescope parallel with the edge of the rule so long as the angle of divergence remains constant and the magnetic meridian is not used for orienting. To use the declinatoire after repairing the alidade, a new so-called magnetic meridian must first be obtained when the table has been oriented with the repaired instrument.

Broken divider points.—Occasionally the dividers are dropped on a rock and one or both points broken. Find a sandstone and grind new points, finishing with the emery paper carried for sharpening pencils.

Broken central ball and socket.—Care must be exercised in leveling to keep the central clamping screw of the plane-table head loose; otherwise there is danger of breaking the ball-and-socket joint when screwing up the leveling screws. If the shell breaks, the instrument might be put in condition for use by placing on the screw a wooden or iron washer that can not come through the broken portion of the plate.

FIG. 6.—TOPOGRAPHIC PARTY

Part 3.—FIELD WORK

PRELIMINARY OPERATIONS

The usual operations preliminary to a topographic survey are (*a*) the organization of the party or the selection of the members of the topographic unit from the personnel of a party engaged in combined operations; (*b*) the establishment of control; (*c*) signal building; (*d*) the preparation of plane-table sheets; and (*e*) the testing of plane-table equipment.

ORGANIZATION OF PARTY

A topographic party usually consists of the topographer, two rodmen, and a table man, besides the necessary personnel for boats or other transportation used and for camp maintenance, if the party is to work from a camp.

The rodmen should be alert mentally as well as physically, and have a knowledge of what the topographer is trying to accomplish. Much of the efficiency of the party depends upon the rodmen selecting suitable stations for setting up the table and using good judgment in giving readings at the proper intermediate points. If they are able to draw a rapid sketch of their surroundings at and between rod readings, the topographer can often save considerable time by not having to visit the points personally to obtain the position of a small stream, an off-lying rock, an opening to a trail, small indentations of shore line, houses, etc.

Two rodmen are needed, one to go ahead of the table and the other to follow or give readings to near-by features.

The plane-table man keeps the table shaded with a large beach-type umbrella to avoid the sun distorting the paper and to protect the topographer's eyes from the glare that the white paper would otherwise cause. He keeps the pencils sharp, watches the rodmen to inform the topographer when one is ready to give a reading, signals the rodmen, and assists in carrying the gear between set-ups.

CONTROL

A topographic survey must have both horizontal and vertical control. This control consists of the accurately determined location and elevation of a certain number of points so that their relative posi-

tions can be plotted on the topographic sheet. These control points form the foundation or framework about which the topographic features are mapped and to which errors are adjusted.

Horizontal control.—The requirements for horizontal control are given in paragraph 8, part 1, and are the same both for topographic and hydrographic surveys. It will be noted that an exact distance between control stations is not specified. It is desirable that stations be located at commanding sites, such as on points, prominent elevations along the coast, etc., and approximate distances are given in order that the surveyor may have reasonable latitude in adapting his control to the configuration of the coast.

The establishment of horizontal control involves the recovery of stations previously established and the location of a sufficient number of additional stations to meet the requirements for control. A more economical and satisfactory topographic survey will be obtained if the control is established first, and this should always be done if practicable (see pars. 9 to 11, pt. 1).

Stations may be located by triangulation or traverse. Triangulation is the better method, as it gives the location of points over an area rather than along a single line. Traverse is usually confined to regions where triangulation would be unduly expensive, if not impossible, or where steep slopes along the shore or on the sides of ravines prevent the location of triangulation stations at points where they can be seen or used by the topographer. Plane-table graphic triangulation may be used for the location of intermediate stations.

Vertical control.—Vertical control may be established by level lines or by vertical angles measured with a theodolite. A datum plane must be determined from which all elevations are measured or computed. As the topographic work of the Coast and Geodetic Survey is mainly along the shore line and the datum plane used is mean high water, level lines are seldom necessary. The elevation of the plane table above this datum plane can be determined at nearly any time by direct observation of the water's surface.

SIGNALS

Control stations that are not marked by natural or artificial objects existing over them must be made conspicuous by erecting signal structures. New triangulation stations and old stations from which the former are located will have signals built for triangulation purposes in accordance with instructions contained in the Manual of Second-order Triangulation and Traverse. Such signals are also suitable for use in topographic work.

The construction of a control-station signal for topographic use alone is very simple. All that is required is a vertical pole centered

over the station mark, supported by a tripod, guy wires, or other means, and made more conspicuous by a flag, crossed banners, or cloth targets. In general, however, the signals used by the triangulator and topographer will also be required for hydrographic work and must be made more conspicuous than would otherwise be necessary, as they must be seen, often for a considerable distance, with the naked eye or through the low-powered telescope of a sextant.

The topographer who is required to build signals for triangulation should consult the manual mentioned above and follow carefully the directions contained therein. Special attention should be given to the marking of such stations, in order that they may be recovered without undue expense at a later date. The methods of marking stations described in the Triangulation Manual will also suggest the precautions to be taken in marking topographic stations, in accordance with paragraph 29, part 1, to insure their permanence.

When building signals for hydrographic use, the Hydrographic Manual should be consulted, and the topographer should familiarize himself thoroughly with conditions such as the distance and directions from which the signals must be seen, the period for which they will be needed, etc.

For topographic use only, very few signals except those at control stations are required. They can be built to suit the purpose required and usually consist of flags, simple banners, or whitewash placed on rocks, logs, trees, etc. Natural objects are used whereever possible.

Important signals to be located by the topographic party should be built in advance of the survey, if practicable, so that the topographer may draw cuts (direction lines) to them from other points and possibly locate them by intersecting cuts from control stations.

The small signals at short intervals along the coast, not required for topographic work but erected and located by the topographer as his work progresses, for use in extending hydrographic work close inshore, will be discussed in a subsequent section.

PREPARATION AND CARE OF SHEETS

Arrangement of sheets.—The base for a sheet plan should be the most suitable map available upon which are plotted the points, determined by triangulation or other methods, to be used for the control of the topographic survey. A nautical chart or other existing map is preferable; if these are lacking, it is necessary to use a reconnaissance sketch. Factors affecting the selection of a base map are accuracy, scale, extent, and amount of detail shown. In the rare case where the topographic work precedes the control survey, the proposed control scheme should be plotted on the map.

120961°—35——3

The layout of topographic sheets on the base map depends upon several important considerations. For inland surveys, it may be taken as a rule that the intervisibility of the points extends across valleys, from summit to summit, or across rivers, bays, and other bodies of water. Generally, for such work, the line of greatest depression of the valley (thalweg) should follow as nearly as practicable the middle of the sheet, regard being had for any abrupt change of direction or importance of lateral features; or, in other words, the areas to be surveyed should be divided as far as possible into water basins, extending from divide to divide, and not center upon a ridge forming portions of two basins. The reason for this is that from either slope of the basin points are visible on the opposite summits which will be common to the sheets which include the adjoining valleys, while from the middle of the valley points will be visible on both summits.

For coastal surveys the sheets are laid out to cover all of the shore line and the area back from the coast that is to be mapped or in which there are features of value for navigation that are to be located by the topographic survey. In the arrangement of individual sheets, essential requirements are that each must include within its limits the stations required for control and must have a sufficient overlap with adjoining sheets to provide a good check on the juncture of contours and topographic features. It is also desirable, but not absolutely essential, to have, on or near each edge of a sheet where another sheet is joined, a station common to both sheets.

It is desirable to cover an area with as few sheets as possible, but this object should not be attained at the sacrifice of suitable overlap of adjoining sheets or of important control. When there are offlying stations, on islands or on an opposite shore, an arrangement of sheets to include such stations deserves careful consideration. Frequently the increased accuracy and progress that will result from having such a station available for check sights will warrant its inclusion, even at the sacrifice of some space on the sheet (see p. 55).

In laying out sheets it will be of material assistance to provide, on a piece of tracing vellum or paper, a plan of the sheet corresponding in size to the scale of the base map. By placing the pattern over the map and shifting its position about over the locality to be surveyed, the limits that include the most favorable conditions will soon become apparent. The size of the pattern may be obtained from the relation between the scale of the sheet and that of the map. For example, assume that a standard-size sheet and a scale of 1:10,000 are to be used and that the scale of the map is 1:100,000. The dimensions of the sheet are 31 by 53 inches, and the size of the pattern will be one-tenth, or 3.1 by 5.3 inches.

The distances in nautical and statute miles that will be included, for various scales, on a standard-size sheet are given in the following table. Another method of constructing a sheet pattern is to ascertain the width and length of the sheet in miles from this table and to lay off the proper dimensions from the mile scale of the base map.

Scale	Nautical miles		Statute miles	
	Width	Length	Width	Length
1/5, 000	2. 06	3. 56	2. 37	4. 10
1/10, 000	4. 11	7. 13	4. 74	8. 21
1/20, 000	8. 22	14. 25	9. 47	16. 41
1/40, 000	16. 45	28. 51	18. 94	32. 83
1/100, 000	41. 12	71. 27	47. 35	82. 07

Projections.—The polyconic projection is used by the Coast and Geodetic Survey for its surveying operations, as there is less distortion than with any other projection. For the comparatively small area covered by a topographic sheet, the angles and distances between plotted positions agree with those measured over the ground so closely that the area can be mapped with an accuracy such that no departure from true scale can be detected. Projection tables and directions for constructing projections will be found in Tables for a Polyconic Projection of Maps, Coast and Geodetic Survey Special Publication No. 5.

Too much emphasis can not be put on the care and accuracy with which projections should be made. The beam-compass points should be sharp, and the marks pricked in the paper as lightly as visibility will permit. The pencil lines should be fine and light. To avoid shrinking or expanding of the paper during the laying down of the projection, the drafting should be done as rapidly as possible and the paper should be shaded from the sun.

The projection lines should not be inked until after the field work on the sheet is completed (see par. 35, pt. 1, and p. 92).

Plotting control stations.—For plotting control stations, the draftsman is supplied with a list of geographic positions giving the distances and azimuths between stations, their latitudes and longitudes, and the equivalents in meters of the seconds of latitude and longitude according to which the points are plotted on the sheet by measuring from the corresponding minutes. Thus, if the position of a station is given as latitude 54° 44′ 34.″189 N., 1,057.2 meters, longitude 130° 56′ 42.″362 W., 756.5 meters, it means that it is 1,057.2 meters north of the 44-minute parallel and 756.5 meters west of the 56-minute meridian.

The accuracy of the plotting may be tested by a measurement of the respective distances between the points with a beam compass, but this must not be considered a substitute for the verification of the projection and plotted stations, as required in paragraph 7, part 1, which must be done by a person other than the one who constructs the projection and plots the stations.

When stations are plotted some time after the construction of the projection, they should be plotted from four directions—that is, from the parallels and meridians on each side of them—thus, in the example given, from parallels 44′ and 45′ and meridians 56′ and 57′. In this way, if the sheet has become distorted so that the distance between the meridians and parallels no longer corresponds to that given in the projection tables, the error is distributed in proportion to the distances of the station from the projection lines.

It is sometimes necessary to base topographic work on a detached scheme of triangulation, executed before the observations to establish the proper datum have been made. Having measured a base, one of the two methods described below may be used:

(*a*) Construct a temporary projection on the sheet. From the best information available, assume the azimuth of the base line and the latitude and longitude of one end of the base. Using the assumed data, compute the positions of the stations and plot them on the temporary projection.

(*b*) Plot from rectangular axes. Starting from one angle of a triangle, preferably the most northerly (or southerly) and easterly (or westerly) corner of the triangulation, compute by means of traverse tables or log functions the latitude and departure of each triangulation station with reference to the initial station, as in traverse computation. Construct on the sheet rectangular axes that will best fit the triangulation net and convert the latitudes and departures to coordinates of these axes. This method requires less work than the one described under (*a*) and is sufficiently accurate for surveys of small extent.

In either case, if the work is done carefully, a regular projection can be constructed on the sheet after the proper datum has been established.

If it is necessary for some special purpose to start topographic work before projecton data are available or a traverse can be computed, plotting by distances is the only method available, and great care, of course, is necessary.

Transferring data mapped by rectangular coordinates.—When engaged in localities where copies of surveys by local authorities or United States engineers may be obtained, information shown by those surveys may be of assistance to the topographer. In revision

work especially, duplication of effort may be avoided by the transfer of data from such surveys. As most of these surveys are on systems of rectangular coordinates, it is necessary to transfer the lines of these coordinates in the area to the polyconic projection on the topographic sheet in order to plot the features desired. As a rule, the distances of the coordinates from the zero of the system are given as well as the geographic position of the zero point.

The relation between plane rectangular coordinates and geographic positions is discussed in Coast and Geodetic Survey Special Publication No. 71. Tables for the transfer of coordinates are furnished in this publication. For any work that might be necessary in the field, a simpler reduction may be used with sufficient accuracy, as illustrated by the following examples:

Example No. 1.—Find the geographic position of a point 40,000 feet south and 160,000 feet east of a point whose geographic coordinates are latitude 46° 16′ 1,073 m., longitude 124° 03′ 99 m.

Latitude—south coordinates

		Meters
40,000 feet		=12, 192
		1, 073
South of	46° 16′	=11, 119
From table	−7′	=12, 968
Latitude:		
Uncorrected	46° 09′ −	1, 849
Curvature	—	193
Latitude [1]	46° 09′	1, 656

Longitude—east coordinates

		Meters
160,000 feet		=48, 768
		99
East of	124° 03′	48, 669
	−30′=	38, 616
		10, 053
	−5′=	6, 436
		3, 617
	−3′=	3, 862
Longitude	123° 25′	245

Curvature correction:

$$\left(\frac{48,768^2}{10,000}\right)\times 8.1 = 4.88^2 \times 8.1 = 193 \text{ m.}$$

Explanation.—The distances in feet of the point on the north-and-south and east-and-west coordinates are converted to meters and to this is applied the number of meters from the given minutes of latitude and longitude to obtain the distance in meters of the point from the even minutes of latitude and longitude near the geographic position. The value in meters of 7 minutes (obtained from the polyconic projection table) is subtracted to get the latitude of the point sought uncorrected for curvature. The correction for curvature (always subtractive) is obtained by multiplying the factor from the table below by the square of the distance (in meters, on the east-west coordinate) divided by 10,000.

A similar reduction in meters is applied to the base longitude 124° 03.[1]

Example No. 2.—Find the geographic position of a point 30,000 feet north and 155,000 feet west of a point whose geographic coordinates are latitude 38° 20′ 426 m., longitude 75° 10′ 315 m.

[1] Use in taking out longitude values.

Latitude—north coordinates

		Meters
30,000 feet		=9, 144
		426
North of	38° 20′=9, 570	
	+5′=9, 250	
Latitude:		
Uncorrected	38° 25′	320
Curvature	−	136
Latitude [1]	38° 25′	184

Longitude—west coordinates

		Meters
155,000 feet		=47, 244
		315
West of	75° 10′=47, 559	
	+30′=43, 668	
		3, 891
	+2′=	2, 911
Longitude	75° 42′	980

Curvature correction:

$$\left(\frac{47,244^2}{10,000}\right)\times 6.1=4.72^2\times 6.1=136 \text{ m.}$$

Table of curvature for X=10,000 meters

Latitude (degrees)	Y in meters	Latitude (degrees)	Y in meters	Latitude (degrees)	Y in meters	Latitude (degrees)	Y in meters
25	3. 7	32	4. 9	39	6. 3	46	8. 1
26	3. 8	33	5. 1	40	6. 6	47	8. 4
27	4. 0	34	5. 3	41	6. 8	48	8. 7
28	4. 2	35	5. 5	42	7. 0	49	9. 0
29	4. 3	36	5. 7	43	7. 3		
30	4. 5	37	5. 9	44	7. 6		
31	4. 6	38	6. 1	45	7. 8		

NOTE.—As the curvature corrections in the above table are given only to the nearest tenth, appreciable errors will result for extremely long distances. However, for distances up to 200,000 feet east or west of the origin the error in curvature is inappreciable for plotting on a scale of 1 : 10,000 or smaller.

Care of sheet.—Constant care must be exercised to keep the sheet clean. A cloth large enough to cover the whole sheet should be rolled up with the sheet to keep the back, which is usually soiled, from rubbing the face. When the sheet is on the table the cloth should be folded back to expose only that portion on which work is being done. Cloths should be kept under the hands to avoid perspiration coloring the sheet. The bottom of the alidade must be cleaned frequently and rubbed over the sheet as little as possible.

A white rubber cloth should be kept handy at all times to protect the sheet from sudden showers. This will often obviate the necessity for removing the sheet for a light shower and then replacing and reorienting. Oilcloth is not as good as rubber sheeting, as it cracks too easily when folded. The rubber or oilcloth cover should be rolled on a round stick when not in use.

If the sheet should become wet, it must be dried slowly, preferably lying flat and weighted down to prevent warping of the paper.

[1] Use in taking out longitude values.

When carried on the board, the sheet must be covered with the cloth mentioned above to keep it clean and to afford some shade from the direct rays of the sun, which would cause excessive distortion. When the sheet is off the board, it should always be carried in the metal tube.

Spare sheets should be stored flat or hung up where they will not be subject to excessive heat, moisture, or dryness.

TESTING PLANE-TABLE EQUIPMENT

Adjustments to the alidade, to be made before use and at frequent intervals during the season in accordance with paragraph 13 of the general requirements, have been described previously. The first adjustments during the season may be made at the initial set-up of the topographic survey, but, as they may take some time, especially if the instrument is badly out of adjustment, it is often desirable to make a thorough adjustment before taking to the field for topographic work. If this is done, only a brief examination of the instrument and possibly a few minor adjustments will usually be required at the initial set-up.

Tests of the telemeter rods are usually made at some convenient time before leaving for the field, as they require suitable testing grounds and may disclose conditions requiring corrections that can not be made conveniently in the field. To test the rods, measure off with a steel tape 100, 200, 300, and 400 meters along a flat, level piece of ground. Set the table over the end stake and place the alidade on the board directly over this stake. Have the rodman hold his rod over the 100-meter stake and caution him to hold the rod vertical (see p. 53). Read the rod and note the error, if any. Repeat on the 200, 300 and 400 meter stakes. If errors are large enough to be considered and it is not practicable to recalibrate the rods, determine the error for readings of 100, 200, 300 meters, etc., by measuring the distances to the points where these readings are obtained. The corrections to be applied to the various rod readings will thus be obtained.

Both the upper and lower one-half, one-quarter, and one-eighth interval horizontal lines should be checked on the 200, 300, and 400 meter pegs, as they may not be equally spaced. If this is found to be the case, the intervals that are more nearly correct should be used in reading distances. All corrections should be recorded and applied to subsequent readings taken during the progress of the survey. In calibrating the rods care must be taken to avoid ground refraction errors (see par. 14, pt. 1, and p. 55).

The bottom of the alidade ruler becomes dirty very quickly from tarnishing of the metal and rubbing over pencil marks and should

be cleaned thoroughly before starting each day's work and as well as practicable at each set-up.

Unless a magnetic station is convenient to headquarters the error of the declinatoire is usually determined during the course of field work. The method used is explained on page 42.

TOPOGRAPHIC SURVEYING

Having completed the necessary preliminary work, the topographer is ready to begin surveying operations. The party proceeds to the point selected for starting work and sets up the plane table. Conditions governing the selection of a starting point are discussed below in the sections relating to the location and orientation of the plane table.

Placing the sheet on the board.—Having assembled the tripod and attached the board securely to the tripod head, placing the sheet on the board is usually the next operation. It must be attached smoothly and firmly so that it will not be disturbed in its position by the friction of the alidade nor by ordinary winds. The long side of the board is equal to the width of the sheet. Therefore, the sheet is put on so that its edges are even with the edges of the short side of the board, and the excess length is rolled up, turned underneath the sides of the table, and fastened with a metal spring clamp, biting from the top of the sheet on the table to the inside of the roll beneath. One clamp at each end of the roll serves to hold the roll ends securely.

The sides of the sheet are sometimes held to the table by similar but shorter clamps, but it is preferable to use the long side clamps, as they prevent the wind from getting under the edges of the sheet and disturbing its adjustment or interfering with the free movement of the alidade. If, however, it is necessary for the alidade to extend over the edge of the sheet, the short clamps should be used and moved, if necessary, so that the alidade may lie between them and not be lifted off the paper by the long clamps. (See fig. 2.)

One end of the cloth used for covering the sheet can be rolled up with one end of the sheet and the other left free to turn back and expose the portion of the sheet on which the immediate work is to be done.

When carrying the table with the sheet on it, care should be taken not to crush the rolled-up portion of the sheet.

Setting up plane table.—To set up the plane table for surveying purposes loosen the tripod-leg screws and grasp one leg of the tripod in each hand. Push the third leg out with the knee and rest the table on this leg. Spread the other two legs and draw them away from the third leg until the table is at the correct height. In this operation

the board should be kept approximately level by sighting across its top at the horizon or estimated horizon.

The height of the table should be such that the topographer can observe through the telescope or sketch on the sheet without stretching or bending the body uncomfortably. A low table is very tiring to the surveyor.

If it is desired to plumb a plotted position on the sheet over the corresponding point on the ground, the table should be oriented approximately by eye and moved and reoriented as required while the plumbing is tested by dropping a small stone from the underside of the board directly under the plotted point, or by sighting the plotted position and point on the ground, along a plumb line held at arm's length, from two positions about 90° apart. Plumbing arms are supplied by instrument dealers but are not required for the scales on which the work of the Coast and Geodetic Survey is usually done.

When the table is in the proper position, the legs should be pressed firmly into the ground. If the set-up site is rocky, care should be taken that the metal tripod shoes are tight and that they rest in niches so that they will not slip. In some cases it may be necessary to chisel small niches in the rock. Finally, the tripod-leg screws must be tightened so that the table will be firm.

To take up the plane table the above operations are reversed. The tripod-leg screws are loosened, two of the legs are grasped, and the table is supported on the third leg until the two or all three legs are together. In carrying the table between set-ups, some table men rest the tripod on one shoulder while others prefer to spread one tripod leg and carry the table astride the neck. For short distances where the footing is poor, as when placing the table in a boat for transportation to the next set-up, the table should be carried in such a manner that it will not fall violently if the table man slips.

Leveling the plane table.—Having the table approximately level as indicated above, loosen the horizontal motion clamp and the central handwheel under the tripod head. Place the alidade on the board so that the fiducial edge of the base is parallel to two of the leveling screws. Turn these screws simultaneously (both inward or both outward) until the bubble of the level on the base is in line with the center of the level and the third leveling screw. Turn the latter to bring the bubble to the center of the level.

Difficulty in turning the leveling screws is an indication that the board has been raised to such an extent as to take up the slack of the central bolt, and the handwheel must be loosened again to avoid danger of breaking the plate. After the table is level, the handwheel is tightened. The topographer should then note whether or not his movements about the table, and especially near the tripod

legs, cause a movement of the level bubble. If the bubble is affected, either the table should be set up more firmly or care taken not to disturb its adjustment.

LOCATING AND ORIENTING THE PLANE TABLE

In using the plane table for the execution of a controlled topographic survey,[2] two things are essential. First, the location of the table must be known so that its position may be plotted on the sheet, and, second, the sheet must be properly oriented at all times; that is, the board with sheet thereon must be adjusted and clamped so that the prolongation of a line drawn through the plotted point representing the position of the table and the plotted position of any other object will pass through that object. Various agencies tend to disturb the orientation of the sheet. Its adjustment should therefore be carefully made and should be checked from time to time during the work at the station and after completion of work.

The simplest method of accomplishing the above is to set up the table at a control station from which a second station is visible, both stations being plotted on the sheet. This method of orientation is illustrated in Figure 7, in which *A*, *B*, and *C* are three control stations and *a*, *b*, and *c* are the corresponding plotted positions of these stations on the sheet.

The procedure is as follows: Set up and level table over station *A*. Unclamp the plane-table movement and place the alidade on the sheet so that the fiducial edge of the base passes through the plotted points *a* and *b* and the telescope points toward *b*. Rotate the board until station *B* is seen through the telescope, clamp the movement, and then move the board by means of the tangent screw until the signal or other object at station *B* is bisected by the vertical line of the telescope.

The table is now oriented provided that the points have been plotted correctly on the sheet and that the proper objects have been sighted. If a third station (*C*) is available, the orientation may be checked by placing the edge of the alidade base on the points *a* and *c* and sighting on *C*. If the latter is bisected by the vertical line of the telescope, the orientation is verified. Failure to bisect *C* indicates an error in plotting the positions or in identifying the stations, which must be corrected, or an unequal change in the dimensions of the paper (distortion), for which allowance must be made as explained on page 65.

[2] The term "controlled topographic survey" is used to denote a survey based on a system of triangulation or traverse stations so that the position, on the earth's surface, of each feature that is mapped on the sheet is shown by its relation to the projection lines of the sheet. In an uncontrolled survey, discussed in a subsequent section, the relative positions of the various features, but not their geographic positions, are determined.

In orienting the plane table it is very important that the two stations be a sufficient distance apart to insure the accuracy of this operation. A distant station on which an accurate pointing can be made should be selected and the distance on the sheet between the plotted positions of the two stations should preferably be over 6 inches. It will be convenient if the distance is not greater than the length of the alidade base; but this is unimportant, as a line between the two positions can be laid off with a straightedge. In the rare case where it is necessary to set up at a station from which no other station, plotted on the sheet, is visible, an azimuth line (from the azimuths given in the list of geographic positions) to some station outside the limits of the sheet may be plotted and used for orienting.

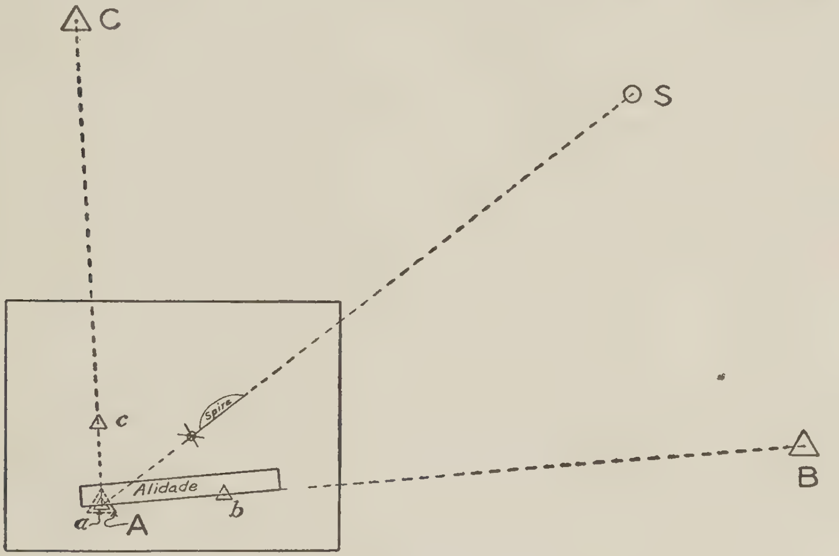

FIG. 7.—Orienting plane table

After the sheet has been oriented, the topographer should sight through the telescope at some object and attempt, using light pressure, to move the table horizontally and vertically. If no movement is noted through the telescope, the table is solid and likely to remain in orientation. In all subsequent use of the table, care must be taken not to jar it or rest the body on it.

Set-up in line with two stations.—If it is difficult or impracticable to set up the table over the station at which work is to be started, it may be located and oriented in line with two stations. This method is illustrated in Figure 8, in which A is the near-by and B the distant station. The table may be set up at any convenient point, such as a or a', near station A and on line with A and B. To establish a set-up

position for the table at a point between two stations as at *a*, the topographer may stand over station *A* and line up a rodman, by eye, on station *B*. Points such as *a′* are established by lining up the two stations by eye. The distance to *A* is measured and plotted on line to give the position of the table, the latter being oriented on the stations *A* and *B* in the manner described above.

This method is especially valuable when the near-by station is a church spire, cupola of a house, or other structure difficult of access. Two men with rods can establish the line between the two stations very easily by lining each other up, in succession, on opposite stations.

Plumbing the station.—When occupying a station for work on scales of 1:10,000 or 1:20,000 and the next plane-table set-up is to be located from the occupied station and is only a short distance away (say about 200 meters or less), great care should be taken to plumb the plotted position over the station. The same precaution should also be taken when occupying the next set-up from which a back sight to the first station is to be used for orienting; otherwise,

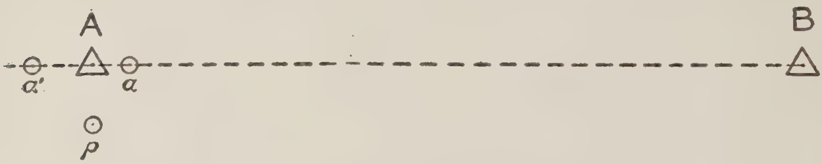

FIG. 8.—Eccentric plane-table set-ups

when working on the above scales, it is not necessary to have the plotted position of the table directly over the station, though it is advisable to plumb the position as closely as possible by eye. An experienced table man, if shown the general location on the sheet of the station to be occupied, will be able to set up the table, without loss of time, so that the plotted point is approximately over the station.

When working on large scales (1:5,000 or larger), the plotted position should be plumbed over the stations under all conditions.

Eccentric set-ups.—The methods described above are the most accurate means available for locating and orienting the table at a control station. They should always be used when working on scales larger than 1:20,000 and for work on any scale if practicable.

When working on scales of 1:20,000 or smaller, however, the use of these methods is not absolutely essential, provided that the distant station used for orienting is not less than 2 miles away. If necessary, the table may be set up a short distance (say from 1 to 3 feet) to one side of the station. On such scales the plotted point representing the station, no matter how fine it may be, covers an appreciable

area of ground, so that there will be no perceptible change in azimuth due to the eccentric position of the instrument.

In such cases, however, it is desirable to obtain a more accurate orientation by pointing the telescope a corresponding distance off the distant station, taking care to point on the proper side of the latter as its image is inverted. This procedure may be followed to advantage in all cases where the plotted point is not directly over the station or over a line between the two stations used for orienting. The proper distance off the distant station can often be judged from the width of the banners or other parts of the signal.

For work on any scale, when the distant station is 2 miles or more away, the table may be located and oriented at a distance up to 10 meters off the line between two stations in the following manner: Set up the table at a point (such as p, fig. 8) estimated to be on a line from station A at right angles to the line AB. Measure the distance Ap and plot p on the estimated line. Place alidade base on the plotted positions of p and B and orient on B. Correct position of p by resecting on A (resection is explained on p. 43).

The distance off the line AB can be extended to 25 meters by orienting with the declinatoire as described below, resecting on A, plotting the position of p on the resection line from its measured distance from A, and then following the directions given above.

MAGNETIC MERIDIAN

At the first station where a strong orientation is obtained the magnetic meridian should be drawn on the sheet. To accomplish this, place the declinatoire on the sheet and release the needle. Move the box until the compass points to zero and draw a line along the edge of the box. This will give the magnetic meridian at the station if the declinatoire has no index error. Care must be taken that no iron or steel, such as knives, metal pencil boxes, etc., is near the declinatoire, and the orientation should be checked before and after drawing the meridian. The general requirements on this subject are given in paragraph 17, part 1. The meridian line should be drawn on some part of the sheet where it will least interfere with the delineation of topographic features.

Orienting with declinatoire.—After the magnetic meridian has been drawn on the sheet, an approximate orientation, which is often desirable, can be made at any time with the declinatoire. The operation is the reverse of that described above; the declinatoire is placed on the sheet along the magnetic meridian and the table is turned until the needle points to zero or to the reading corresponding to the error

of the instrument. If the magnetic declination of the station is known, the same result can be accomplished without a magnetic meridian line by placing the box along a true meridian and turning the table until the needle reads to the right or left of the zero according to the amount and direction of the declination.

Testing the declinatoire.—Testing the declinatoire in accordance with paragraph 17, part 1, is done at some station where the declination is known or is to be observed with a declinometer. If the declination is less than the graduated angle of the declinatoire, the table is oriented on a distant station as described heretofore, the instrument is placed along a true meridian line of the projection, and the average reading of the north and south ends of the needle is noted. The difference between this reading and the known declination is the error of the instrument. If the declination is too large for a reading in this manner, the magnetic meridian is drawn as described in the first paragraph of this section, its angle with a true meridian being measured and compared with the known declination.

In the note, required on the sheet, relative to the error of the declinatoire, care must be taken to indicate clearly the direction of the error.

GRAPHIC TRIANGULATION

A very satisfactory use of the plane table is for graphic triangulation whereby features at a distance can be located, without the necessity for measuring distances, by intersection and resection.

Intersection.—It has been stated that when the table is set up and properly oriented a line prolonged through the plotted position of the table and the plotted position of any other object will pass through the object. It is evident, therefore, if a line is drawn on the sheet so that it passes through the plotted position of the table and would pass, if prolonged, through an unlocated object, that the position on the sheet of the latter must lie somewhere on the line.

The method of obtaining such lines is as follows: Assuming in Figure 7 that the table is set up and oriented at station *A* and that an object exists at *S*, the position of which is unknown, the alidade is placed so that the edge of the base passes through *a*, and the object at *S*, seen through the telescope, is bisected by the vertical line of the telescope. The position on the sheet of *S* then lies on a line drawn along the edge of the base—that is, on the line marked "spire" in the figure. Such a line of position is called a "cut" or "ray."

The position of the object on the line is, of course, unknown, but if the table is set up and oriented at some other suitable point, as at

station B, a second cut from the new station will locate the position of S at the intersection of the two cuts. The position may be verified by a third cut from another station such as C.

If practicable, three or more cuts, at least two of which intersect at an angle between 30 and 150°, should be obtained to each object located by intersections. Adjustment of position in case of failure of cuts to intersect at a common point is discussed on page 45.

At each station occupied the surrounding territory should be scrutinized to select all objects to which cuts are desirable. The first cut to an object is usually marked in a distinctive manner, and the first intersection is marked by ringing it in pencil. If numerous cuts are taken, it may be desirable to number them and keep a record of them in a notebook.

A chisel-pointed 5H or 6H pencil is best for drawing lines; a sharp-pointed 4H pencil is generally used for lettering. Care must be taken to keep the flat side of the chisel-pointed pencil against the edge of the base and to hold the pencil at a constant angle to the plane of the paper, so that there will be no deviation of the line from the edge of the base. To avoid confusion and unnecessary marking of the sheet, each cut should be drawn only in the general location of the object but must be drawn so that, if extended, it will pass through the center of the plotted point representing the position of the station from which the cut is obtained. If practicable, the same edge of the base should be used for all cuts as a precaution in case the two edges are not exactly parallel.

Resection.—After the table has been set up and oriented at a located station and one cut has been obtained to an unlocated station, there is another method by which the latter can be located. Instead of obtaining cuts from other stations, the topographer may proceed directly to the unlocated station (point S in figs. 7 and 9) and determine its position in the following manner:

Referring to Figure 9, set up the table over S and place the alidade so that the edge of the base is against the cut line and passes through the plotted position (a) of station A from which the cut was obtained (see "orientation lines" below). The telescope, of course, should point toward a—that is, exactly opposite to its pointing when the cut was obtained. Swing and clamp the board so that the signal at A, seen through the telescope, is bisected by the vertical line of the latter. This operation orients the table. Next place the alidade so that the edge of its base passes through the plotted position (c) of station C, or any other station suitable for use, and the signal at C is bisected by the vertical line of the telescope.

Having in mind the conditions that obtain when the table is oriented, it is evident that the position on the sheet of *S* must lie somewhere along the edge of the alidade base. A short line drawn along the edge to intersect the first cut, therefore, locates *S* at the point of intersection of the two lines. This operation is called "resection." A second intersecting line to check the position may be obtained by resection on station *B*. Previous remarks relative to pencils to be used and precautions to be observed in drawing cuts also apply to resection lines. On account of possible instrumental errors and distortion of paper, near-by stations should be given preference for resection purposes.

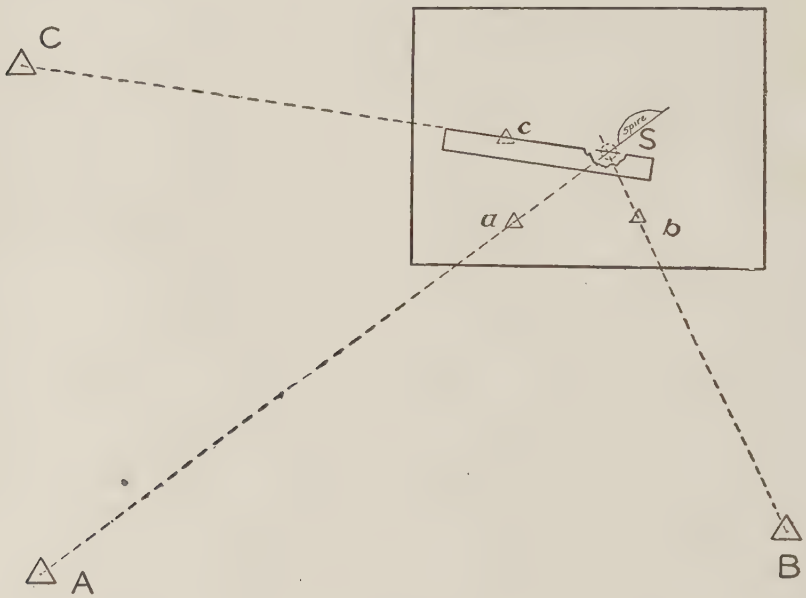

FIG. 9.—Resection

If the table can not be set directly over station *S*, it is entirely practicable to place it near *S* and in line with *S* and *A*. The sheet is then oriented as just described and is located by resection, after which the position of *S* can be determined by measuring its distance from the table. Having located a station by resection, cuts can be taken to locate any other unlocated points.

As a general rule, the location of stations by resection is confined to cases where it is necessary to occupy such stations for other topographic work.

Orientation lines.—A method of orientation referred to above and used extensively in topographic work is illustrated in Figure 10. In this figure, *a* is the plotted position of a station at which the table is set up and oriented and *b* is the plotted position of a future set-up of the table. The line on which *b* is located is obtained by a cut, and the distance between the two stations may be obtained in several ways. When the cut is taken from *a*, the telescope of the alidade, of course, points in the direction of the solid arrow.

When the point on the ground corresponding to the plotted position *b* is occupied, the table is usually oriented by reversing the alidade, so that the edge of the base remains in contact with the points *a* and *b* while the telescope points in the direction of the broken arrow line, and by backsighting on the first station.

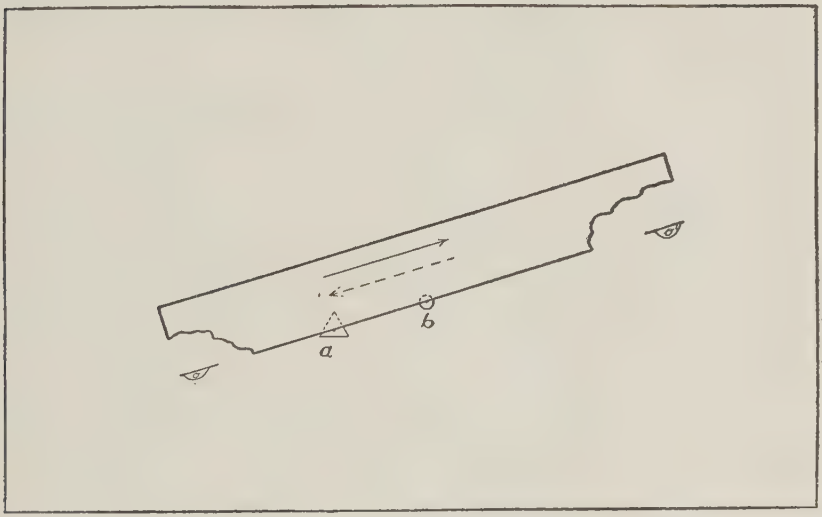

FIG. 10.—Orientation lines

In order that the second orientation may be as accurate as possible, it is desirable that the alidade be pointed, as closely as practicable, in exactly the opposite direction from the first pointing. For this purpose, advantage should be taken of the full length of the alidade base, when the first cut is obtained, by drawing short orientation lines along the edge of the base at both ends.

Thus, when the cut from *a* to *b* is obtained the lines *o* and *o′* are drawn (in fig. 10, corners of the base are cut away to show these lines). When the second station is occupied it is obvious that the alidade will be reversed more exactly by placing the edge of the base against the orientation lines than by depending on two points, or a point and a short line, relatively close together.

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Orientation lines are always drawn when a cut is taken to a station where the table is to be set up and oriented by a back sight on the station from which the cut is taken; otherwise they are not required.

Adjustment of position.—When three cuts to an object from a series of stations fail to intersect at one point they form a triangle called the "triangle of error." The usual causes for such discrepancies and remedies therefor are given below:

(*a*) *Erroneous plotting of control stations.*—This is unlikely if the plotting has been carefully checked, but it may be desirable in some cases to recheck the positions.

(*b*) *Failure to identify the object from one or more of the stations, or, if the object is indefinite, to sight on the same point of the object from all stations.*—This should be eliminated by careful pointings from each station; if unavoidable, it can often be corrected by additional cuts from other stations.

(*c*) *Small angle of intersection between two cuts.*—This should be corrected by a fourth cut from a suitably located station; adjustment of position, in case a fourth cut can not be obtained, is discussed below.

(*d*) *Distortion of sheet.*—Large errors due to abnormal distortion should be eliminated by allowances at the stations from which the cuts are obtained (see p. 65). Errors caused by slight distortion may be considered as a part of the discrepancy due to small errors in orientation and adjusted as described below.

(*e*) *Errors in orienting table at stations.*—Large errors should be avoided by checking orientation as described previously. Adjustment of small errors is discussed below.

If there is a triangle of error and the topographer is reasonably certain that the discrepancy is not due to the causes mentioned in paragraphs (*a*) and (*b*) above, to large errors of orientation, or to large distortion, it is probably caused by small deflections in azimuth due to the limitations of the instrumental equipment. Such triangles of error should be quite small and may be adjusted by selecting the most probable position of the object.

An error in orienting the table will cause the same angular error in the bearing, as shown by the cut drawn on the sheet, of any object observed. Under this condition it is obvious that the distance of the true position, on the sheet, of the object from the cut will increase with the distance of the object from the table.

In adjusting a triangle of error caused by small errors of orientation due to the limitations of instruments and possibly to slight distortion, the topographer has no way of knowing the direction or extent of the error at each station, and about the only method of adjust-

ment available is to plot the position of the object inside the triangle of error. For the reason stated in the preceding paragraph, however, the point should be plotted so that its distance from each cut is proportional to the distance between the object and the station from which the cut was obtained.

When two cuts intersecting at a small angle are intersected strongly by a third cut, the above method should be used with caution. Assuming that the table is oriented and located with equal accuracy at all stations, the most probable position is on the line from the station nearest the object, at or very near the point of intersection of the cut forming the stronger angle with this line.

A short line representing a cut from a station should never be prolonged for any considerable distance unless an orientation line or other point on the correct bearing is available.

When resection lines form a triangle of error, the adjustment is made in accordance with the rules pertaining to the three-point problem given on page 57.

Extension of control.—Graphic triangulation is sometimes used to extend control a short distance from a base formed by two triangulation or traverse stations. Triangulation with the plane table, of course, is not as accurate as triangulation with a theodolite, or traverse with theodolite and tape, but it is the most accurate method available for locating objects with the plane table and, if executed with reasonable care, will give good results for short distances. Its use in the manner described below is usually confined to the two following general cases:

(*a*) For the final control survey of relatively unimportant areas of moderate size where it is considered that more precise control is not required but where the extent of the area requires special methods in order to secure an accurate and expeditious topographic survey.

(*b*) For establishing preliminary control in an area where triangulation with theodolite is contemplated but where it is desired to start topographic or hydrographic work before the final control survey can be begun. In this case, the stations and scheme used for graphic triangulation are the same as will be used for the subsequent theodolite triangulation.

A typical illustration, applicable to either case, is given in Figure 11. In this example, there are triangulation stations (A and B) at the entrance points of a small bay but no stations inside, and it is desired to provide the latter by extending graphic triangulation from the base AB.

The first operation is a reconnaissance to select sites for stations, such as those indicated by circles in the figure—that is, to lay out a triangulation scheme. The principles involved are the same as for all triangulation work. Thus, starting from the base AB, angles

are measured to locate stations C and D and provide a second base line CD for going ahead. Each section of the triangulation is called a "figure." In the illustration the quadrilateral $ABCD$ is the first figure of the scheme. The main object to be attained in laying out the scheme is to place the stations so that they can be located by strong intersections (of three or more lines, if practicable) and are on commanding sites such as points, off-lying islets, etc. Suggestions and illustrations of various triangulation figures for use in adapting the scheme to the configuration of the region under survey will be found in the Manual of Second-order Triangulation and Traverse.

Having selected the sites for stations, suitable signals are erected (see p. 28). It is desirable that the table be set up with its plotted position plumbed over the station; if this is impracticable at any station, the table should be set in line with two stations, and its exact position, after work at the station is completed, should be marked by a flag for use in orienting by a backsight. Great care must be taken to observe the precautions mentioned previously for drawing cuts and resection lines. Orientation lines should be drawn for each cut unless it is certain that they will not be required for orienting.

If work of this nature can be performed entirely in one day of clear, fine weather, when the paper is fresh and thoroughly dry, less difficulty from distortion of the sheet will be encountered. In any case, to minimize the effects of such distortion, the work should be completed as quickly as possible, usually without delaying for other topographic work in the area until the triangulation is completed.

Plane-table operations may be started either at A or B. If the former, the station routine should be about as follows: Set up table at A; orient on B; draw magnetic meridian; cut to C and D and to any supplemental objects, such as X, that it is desired to locate by intersections.

Theoretically, the observations at A and B are for the purpose of locating C and D, and no additional cuts are necessary. Actually, the table is located and oriented more accurately at A and B than will be the case at any other station, and it is therefore advisable to cut from these stations to all other stations of the scheme that can be seen. Even if the stations are so distant that they can not be reached by the alidade base, direction lines and orientation lines should be drawn on the sheet.

Therefore, at station A, cuts should be taken to E, F, G, and H. When these stations are occupied, the table should be oriented by a backsight on A or B.

Next, set up table at B; orient on A; cut to C, D, E, and to supplemental objects. Then set up table at C; orient on A (or B); and check first intersection of cuts by resecting on B (or A). Place

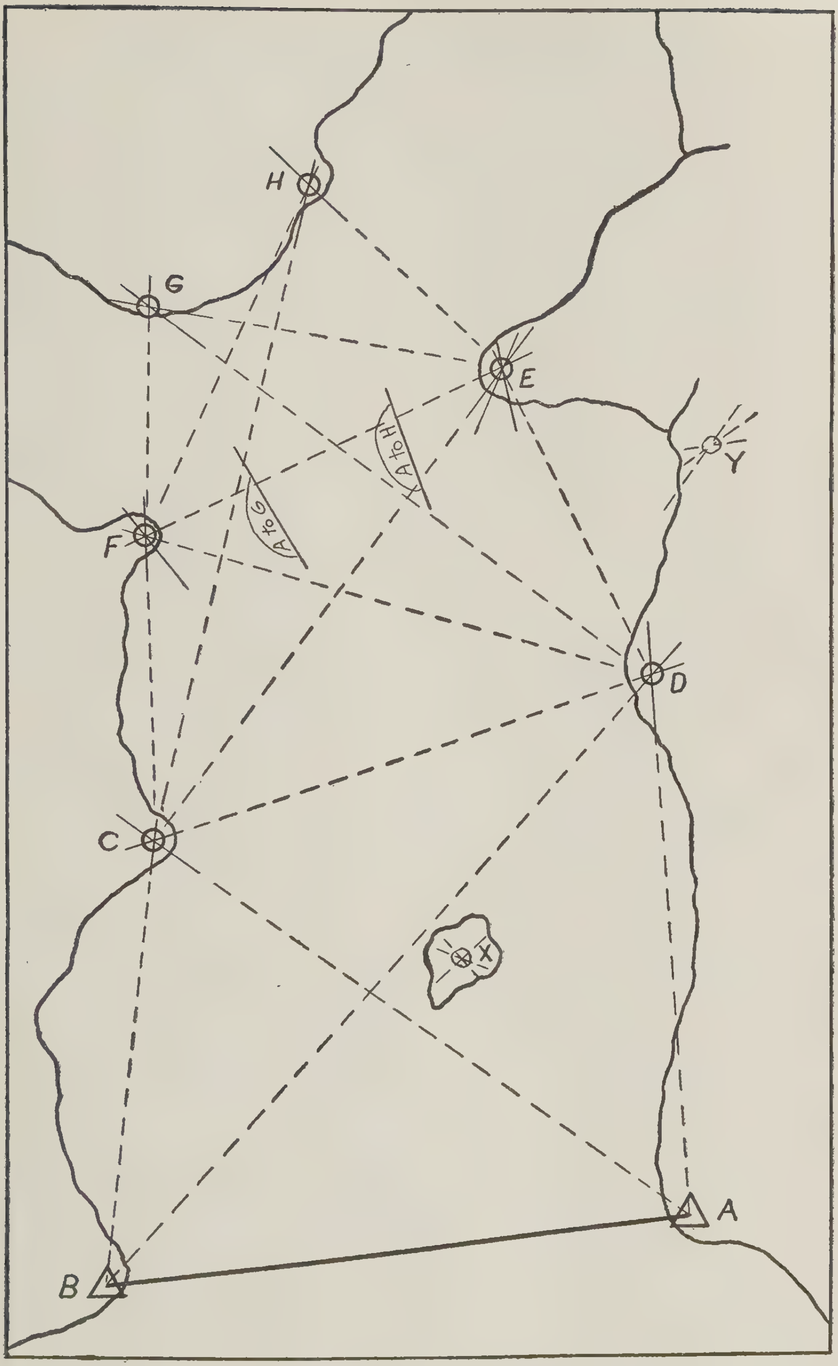

FIG. 11.—Plane-table graphic triangulation

alidade so that edge of base passes through intersection at C of cuts from A and B, and the signal at D is bisected by the vertical line of the telescope. If the edge of the base now passes through the intersection at D of cuts from A and B, the positions on the sheet of C and D are established. Short lines should then be drawn along the edge of the base to show the intersections at C and D.

If the edge fails to pass through the intersection of cuts at D, large discrepancies must be investigated and corrected. If the triangle of error is so small that it is probably due to slight distortion of the sheet or limitations of the instrument, the discrepancy may be adjusted. The method of adjustment will depend on various conditions and must be left to the best judgment of the topographer. In the case illustrated, the intersection at C is a little stronger than at D and ordinarily would be given more weight. Possibly a sight on X, where the intersection of cuts from A and B is very strong, will aid in establishing the most probable position of C. In any case, final adjustment should not be made until the table is set up at station D, where orientation on one station and resection on the others may give further information.

Having established the positions of C and D, cuts are taken to advance stations, including those beyond the next figure of the scheme, work at all stations being essentially a repetition of that described above. If information obtained at D makes it desirable to adopt a different position for C, it will be necessary to reoccupy the latter or to adjust the cuts observed at that station.

No dependence should be placed on positions obtained by cuts that intersect at very small angles. Thus, in fixing the position of station H, no consideration should be given to the intersection of the cuts or resections from C and F. Ordinarily, H should be located on the cut from C (or A) at a point established by the intersection of the cuts from A (or C) and E, the cut from F being used only to detect any large error in azimuth of the cut from C.

When the topographer is a subordinate member of a party, all cuts and resections, in so far as practicable, should be preserved on the sheet until the chief of party has an opportunity to review the work.

Surveys in advance of control.—Graphic triangulation may also be used to advantage in some cases to provide preliminary control when there is no base, established by more accurate methods, from which to start work. Thus, referring to Figure 11, it may be necessary to establish the base AB by theodolite triangulation from another base more or less remote and also desirable to start work in the bay before the former work can be completed. This procedure should be limited as much as possible but is sometimes necessary in order to employ all units of the party to the best advantage.

Likewise, it may be desirable to survey an isolated bay or similar feature, for use as a harbor of refuge or other purpose, in an unsurveyed region into which accurate control may not be carried for some time.

In either case it is necessary to measure a base from which to start graphic triangulation. This base should be measured very carefully by traverse with theodolite and tape, if practicable; otherwise by traverse with plane table and stadia (see par. 11, pt. 1).

Preliminary work includes the selection of a site for a base in addition to selecting sites for stations and building signals. For the survey illustrated in Figure 11, any line, such as *AD*, *BC*, *CF*, etc., offering the best conditions for the base measurement might be selected, or it might be possible to shorten the base by utilizing the island station *X* as one of the main scheme stations.

Assuming that the line *AD* is to be measured as a base, the routine should be about as follows: Using a topographic sheet without projection, set up at *A* and assume a position of this station and an orientation whereby the area to be surveyed will come within the limits of the sheet. Lay off check distances at several places on the sheet in accordance with paragraph 7, part 1. Draw magnetic meridian and cut to all signals in sight, as in all graphic triangulation.

If the distance from *A* to *D* has been measured with a tape, plot this distance on the cut to *D*. If the distance is to be measured by stadia, the next operation is to run a careful plane-table traverse from *A* to *D*, using every precaution to measure the distance accurately and to keep the table in orientation (methods of traversing are described on p. 52). If the position of *D* by traverse does not fall on the cut, a small difference may be adjusted, but large discrepancies must be investigated and corrected.

Next set up at *D*, orient by a backsight on *A*, and traverse to the latter, adjusting or investigating errors in azimuth or difference in distances by the two measurements, as indicated above.

Having the positions of *A* and *D* plotted on the sheet, graphic triangulation should be extended as described heretofore.

True meridian.—If the preliminary survey is to be published before control has been established, it is necessary to provide data for drawing a true north-and-south line. This is done by drawing from a point on the sheet, when the table is in position, a line in the vertical plane through Polaris and the point occupied and recording the time of observation. The azimuth of the star at that time being known, a true north-and-south line can accordingly be set off.

If a small transit instrument is at hand and carefully adjusted for movement in vertical plane, the horizontal angle from Polaris to some illuminated point distant ½ to 2 miles, subtended at the point oc-

cupied, can be measured and the true azimuth then turned off and put on the sheet by daylight.

If no transit is available and the vertical range of alidade is insufficient to observe Polaris, an illuminated plumb line may be used for the alignment.

Marking stations.—Stations established by graphic triangulation should be marked in a permanent manner, preferably by standard hydrographic station marks, and described on Form 524. If such stations are located later by theodolite triangulation, the station mark may be retained, but the station should be described on Coast and Geodetic Survey Form 525, Form 524 also being submitted if shore-line data are observed at the station (see pars. 29 and 30, pt. 1).

TRAVERSING

In order properly to map all topographic features required for chart construction, it is usually necessary to set up, locate, and orient the plane table at one or more intermediate sites between control stations. This may be accomplished by a plane-table traverse between stations, by graphic triangulation, by solutions of the three-point or two-point problems (described in subsequent sections), or by a combination of these methods.

In general, the nature of the coastal topography is such that, for intermediate set-ups, the topographer must depend principally on traverse, supplemented to a certain extent by the other methods.

A traverse is a series of points connected by azimuths and distances. In a plane-table traverse, the azimuth is carried by direction lines (cuts) and distances are obtained by stadia. The operation of running a traverse is illustrated in the upper part of Figure 12. Points *a* and *b* are the plotted positions of stations *A* and *B*. It is desired to start at *A* and traverse to *B*. The procedure is as follows:

Set up and level table at *A* and orient on *B* or any other suitable station. Send a rodman ahead to select the next "set-up" site for the table.

The selection of suitable set-up points is an important duty of the head rodman and he should be trained so that he will show good judgment in this respect. Distances between plane table stations preferably should be from 300 to 600 meters, although this will depend in a large measure on the configuration of the region. Such stations should be well located both for mapping adjacent topographic features and for seeing ahead to the next set-up. Distances between points should be balanced, if practicable. For example, there is no advantage in having one distance 500 meters if the next can be only 100 meters and conditions are such that two 300-meter distances will serve as well.

The rodman holds a telemeter rod over the point selected. He should be careful to hold the rod vertical by standing erect (facing the table) and balancing it lightly between his finger tips directly in front of his body. He should see that there is nothing between the rod and the table and that the light shines on the face of the rod. To insure the latter, it is sometimes necessary to slant the face of the rod a little from its usual position normal to the line of sight.

When the rod is up, establish its azimuth from *a* by a cut in exactly the same manner as has been described heretofore. Draw the cut line along the edge of the base at the approximate position of the rod and also draw the usual orientation lines.

Measure the distance carefully by a reading on the rod. This may be done before or after the cut is obtained, but the latter is preferable.

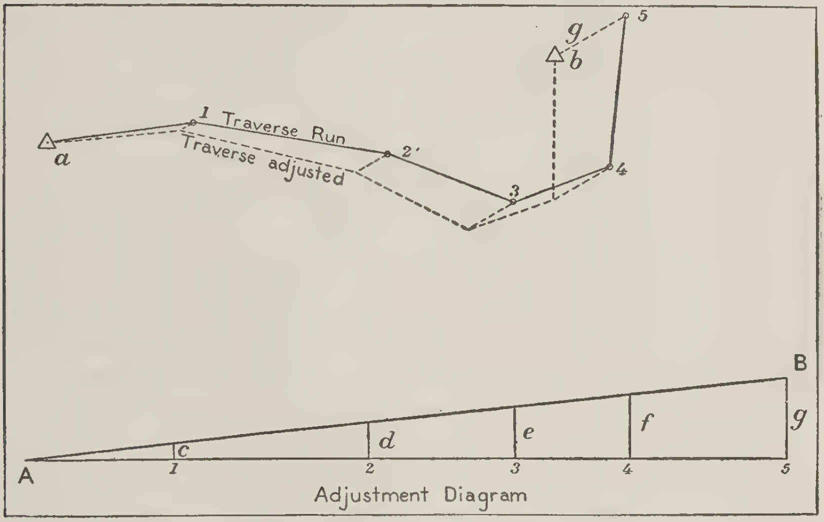

FIG. 12.—Plane-table traverse and adjustment

If some other position of the alidade on the sheet is more convenient, the reading need not be obtained with the edge of the base passing through *a*. The alidade may even be removed to another support abreast the table in case the view from the latter is obstructed by some object, such as the limb of a tree, that cuts off a part of the rod.

Correct the reading for stadia error (see p. 35) and, if rod and table are not at approximately the same elevation, read the vertical angle and correct the stadia reading for the inclined sight (see p. 77). Using dividers and metric scale, plot the distance on the cut to obtain the position of the next set-up (station No. 1 in Figure 12) and signal the rodman that the reading has been completed.

The rodman should then mark the point where the rod was held, by a small flag or other conspicuous object, and proceed to the second

intermediate station or to the next point where he is to give a rod reading. This assumes that the rodman is experienced; otherwise it will be best for him to remain at the first set-up until the topographer can give any necessary instructions.

Having completed work at the first station occupied (station A), move instruments to plane-table station No. 1. If the table was not placed directly over A so that the signal is available for back sighting, a flag must be left to mark the point where the table was set up. It is sometimes desirable to have the rear rodman remain at the station, so that a second reading on the rod can be obtained from the next set-up to check the distance. This is especially desirable for distances over 300 meters, when the light on the rod is better in the back-sight direction and when there are no signals available for checking the distance by resection.

Unless the alidade is placed in its box for transportation between set-ups, it should be carried by the topographer, since care is needed to protect it from injury. A convenient method of carrying this instrument is to rest the standard on the forearm and grasp the end of the base which is held nearest the body.

Set up the table at station No. 1, reverse the alidade on the orientation lines, and orient table by a back sight on A or the object left to mark the site of the table. The remainder of the traverse is a repetition of the work described above. Successive plane-table positions are established until station B is reached. The difference between the plotted position of this station and its position by traverse is the error of the traverse. The adjustment of this error is treated below. Work at each station required for the delineation of topographic features is described on page 67.

Remarks on page 43 relative to pencils, etc., also apply to traversing. In all topographic work, lines that are to be erased should be drawn lightly so that they can be removed without destroying the surface of the paper. A damaged surface collects dirt more easily and may result in blotting when the sheet is inked. All pencil work that is to remain on the sheet should be examined at intervals and freshened if necessary. In setting off distances on dividers, it is preferable to hold the scale in the hand.

Skip station.—In some regions that are barren of detail, so that plane-table stations at moderate intervals are not required for the delineation of topographic features, it may be desirable to establish a set-up position so far from the station occupied that the distance can not be read with the telemeter rod. For this purpose a skip station, as illustrated in the upper section of Figure 13, may be used. In this illustration, a is the plotted position of the station occupied, (1) is the skip station, and (2) is the next set-up position.

Having oriented the table at station A, sight on a rod or other object at (2) and draw the cut and usual orientation lines. Send a rodman to some intermediate point such as (1), obtain a cut and rod reading, and plot the position of the point. Then proceed to (2), orient by a back sight on A, read the distance to the skip station, and plot (2) on the cut from a, according to its distance from (1). If the skip station is so situated that the angle at (2) between (1) and a is 30° or more, (2) can be located by resection on (1), the distance being used to check the position.

Telemeter errors.—The source of the largest systematic errors in stadia measurements lies in the different refractive power of the air strata at the bottom of the rod as compared to those at the top. All stadia readings within 1 meter of the ground should be avoided, especially in hot climates or over sand beaches, as only readings above this limit are practically free from error. When necessary to use the full length of the stadia rod, attach to the bottom of the rod an extension piece without graduation.

Use of other methods.—In executing a traverse the topographer should be alert to take full advantage of the various means of locating and orienting the table when, by so doing, he can secure greater accuracy or increase his progress without sacrifice of accuracy. A control station off the line of traverse and so situated that resection lines from it form strong intersections with the azimuth lines (cuts) of the traverse is especially valuable in this respect.

Possibilities of combining the various methods are indicated in the lower part of Figure 13, representing a section of coast between control stations A and B, station C being located on an off-lying island.

Assuming that a traverse is being run from A to B and that (1) is the first intermediate station, after the table is oriented at (1), the distance by rod reading from A can be checked by resection on C (graphic triangulation). If the distance is so great that the rod reading is questionable and it is known that the orientation is strong, the distance by resection should usually be accepted. For this purpose the angle of intersection should not be less than 30°, and a larger angle is preferable. Under certain conditions, such as a shore line from A to B rather barren of detail and difficult for traverse, it might be advisable to provide small signals at suitable intervals (sketching adjacent detail as each signal is erected) and locate the signals by cuts from A, B, and C, thus avoiding the necessity for a traverse.

Figure 13 will serve to illustrate another practice that is sometimes quite desirable. If the configuration of the point on which (1) is located is such that no position can be selected that will see both A and B, two or more plane-table positions a short distance apart will be required in order to traverse around the point. Assuming

that a second set-up at (2) is required (the distance may be only a few meters), this position can be located very accurately from (1). When the table is set up at (2), however, it will be very difficult to orient it accurately by a backsight on (1) only a short distance away. In such a case, it will usually be preferable to disregard (1), to place the alidade on the plotted positions of (2) and some distant station such as *B*, and to orient on the latter.

If a position on the point that sees *A*, *B*, and *C* can be selected, the conditions are excellent for locating and orienting the table by the three-point problem (see p. 57). From this position a traverse might be run to *B* or a signal erected and used with *B* and *C* for additional three-point positions between the first position and *B*.

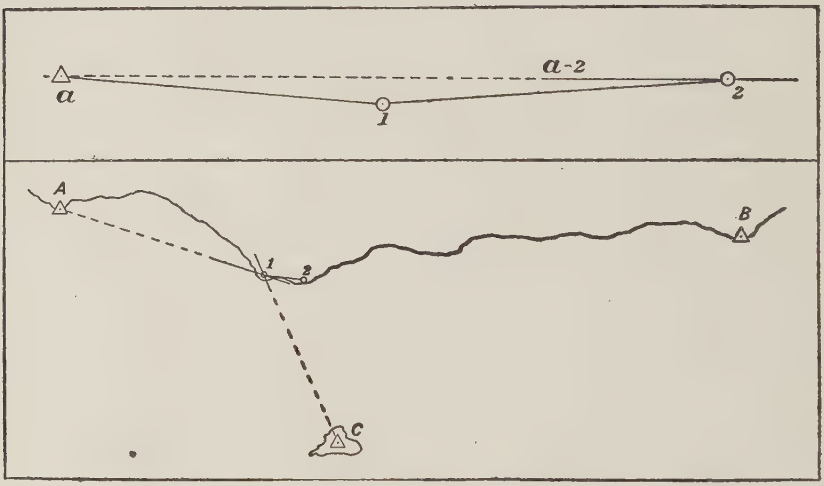

FIG. 13.—Skip station and use of various methods

System of signaling.—Every effort should be made to have the work proceed in an orderly manner without the necessity for shouting or useless gestures. For this purpose a simple and definite system of signaling should be arranged. It is best to have a separate object with which to signal each rodman; such as a different colored flag for each or a hat for one and a handkerchief for the other. The following signals are suggested:

Completion of rod reading.—Wave arms back and forth from a vertical position over the head down to the sides of the body; or wave flag back and forth from a horizontal position on one side to a similar position on the other side.

Rod reading desired, or ready to read rod.—Hold flag vertical and stationary over the head.

Rodman to decrease his distance from table.—Wave flag back and forth from horizontal to vertical position on one side of the body.

Rodman to increase his distance from table.—Same as last signal but on opposite side.

Rodman to move to right or left.—Hold flag horizontal and stationary in desired direction.

"Set-up" point desired.—Wave flag in circle over the head.

Rod reading given for a "set-up" point (given by rodman).[3]—Wave rod from side to side, or hold it edgewise, until topographer holds flag vertical.

Adjustment of traverse.—A traverse between two control stations will seldom close exactly. Any error of closure must be corrected either by adjustment or by rerunning the traverse in accordance with paragraph 12, part 1. It is more likely to be due to erroneous distances than to errors in azimuth, especially if the table is set up and manipulated properly and short distances between set-ups are not numerous.

A traverse is adjusted by moving each plane-table position in the proper direction along a line parallel to the line joining the closing station and the position of this station by traverse. The distance that each position is moved should have the same ratio to the total error that the distance of the position from the initial station has to the total length of traverse.

This proportion is best obtained graphically by means of an adjustment diagram (see fig. 12). In the upper illustration of this figure the direction and amount of the closing error is shown by the line g connecting the plotted position b with the position of the station by traverse. To construct the diagram, from one end (A) of a straight line lay off points 1, 2, etc., at intervals equal to the distances on the sheet (along the traverse line) of the corresponding plane-table positions from the initial station.

At the last point (5) erect a perpendicular equal in length to the amount of the error (g). Connect the other end of this line with A by the line AB. At points 1, 2, etc., erect lines perpendicular to the line A–5. The lengths of these lines between AB and A–5 give the amounts that the plane-table positions are to be moved. The adjustment and the adjusted traverse is shown by the broken lines in the upper part of the figure.

All topographic detail that was mapped from each station should be adjusted to conform to the adjustment of the station. Adjustments should be made at the first opportunity, while all facts are remembered clearly. A description of each adjustment must be given in the descriptive report accompanying the sheet.

THREE-POINT PROBLEM

When three control stations or other previously determined points can be seen *and are suitably situated*, the plane table can be located

[3] As the rodman may give several rod readings on his way to the next set-up position, the reading at the latter must be distinguished so that the topographer can read the rod and make the pointing with special care and also draw the orientation lines which are not required for the other readings.

and oriented simultaneously by applying the principle of resection to effect a graphic solution of the three-point problem. The advantage of this is quite evident, as it allows the topographer to set up the table at commanding sites, for mapping adjacent topographic features, without the necessity for previous cuts to the site, or for traversing between control stations which may be laborious, especially along coasts where walking is difficult.

Having in mind the principles of orientation, it is evident that, when the table is properly oriented, resection lines from two or more stations will intersect at a point on the sheet corresponding to the position on the ground of the table. If the table is not oriented accurately, resection lines from three stations will form a triangle of error, the size of which increases with the error of orientation.

The strength of the position and orientation depends chiefly on the relative positions of the three stations used. The principal considerations to be remembered in selecting control stations are as follows:

(*a*) A strong position will be obtained when the position sought is inside the triangle formed by the three control stations, or when the latter are nearly in line, or the center station is nearer than the others, with no angle less than 30°.

(*b*) A weak position will generally result from using two stations so situated that the angle between them is small. An exception to this occurs when two stations a considerable distance apart are in range, or nearly in range, with the nearer station the center one, provided the angle to the third station is not less than 30°. When the more distant of the two stations is in the center, however, such a position may be very weak.

(*c*) A position is indeterminate when the point sought lies on or near the circle passing through the three stations; the position weakens as the point approaches this circle.

Location and orientation of the table by this method involve the selection of suitable control stations, securing a triangle of error by resecting on the three stations, and interpreting the triangle of error in order to determine the position of the table. The procedure is as follows: Set up and level the table and orient it approximately. If the approximate position of the table is not known, the declinatoire may be used conveniently for the preliminary orientation. Sight on the control stations and draw the resection lines, as explained previously, to form the triangle of error. The position of the point sought can then be estimated very closely by observing the following rules:

I. The point sought is on the same side of all resection lines; that is, either to the right or left (as the observer faces the station from which the line is obtained) of all lines.

II. The distance of the point sought from each resection line is proportional to the distance of the point occupied from the station from which the line is drawn; in other words, the distance from the lines is proportional to the length of the lines if prolonged from the point to each station.

Having estimated the position of the point sought, place the alidade so that the edge of the base passes through the plotted point and the plotted position of the most distant station (always use the most distant station for orienting). Orient on the latter and resect on the two nearer stations. If the position of the point sought was not estimated accurately, a second, but smaller, triangle of error will result, and the operation must be repeated until the correct position of the table is determined. The accuracy of the first estimate will increase with practice.

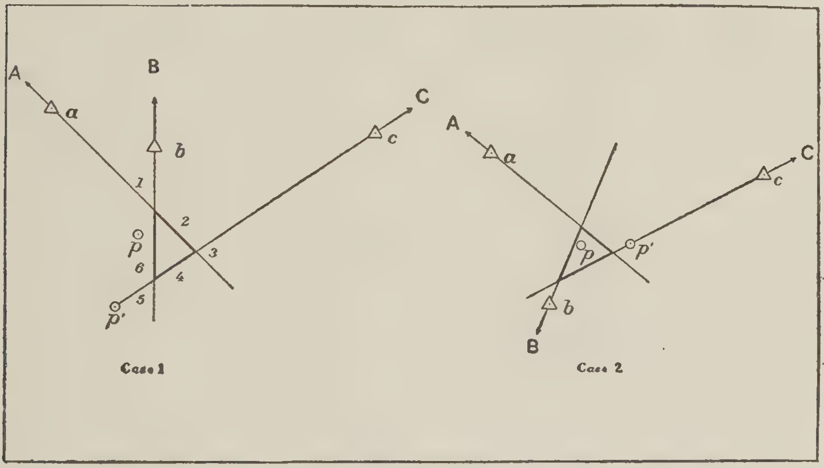

FIG. 14.—Three-point problem

This method may be understood by reference to Figure 14, in which a, b, and c, are the plotted positions of the stations A, B, and C. The triangle of error, formed by the intersections of the resection lines passing through the plotted positions of the stations, is indicated by heavier lines. The position of the table assumed for the first orientation is shown at p'.

In case 1 the plotted position (p) of the table must, in conformity with Rule I, lie either in sector 3, to the right of all resection lines, or in sector 6, to the left of all lines. By Rule II it must lie in sector 6 in order to be nearer to the line from the nearest station (B) than to the lines from the other stations. It is accordingly plotted in sector 6 at the proper proportionate distances from the three lines.

In case 2 the point p must lie inside the triangle of error in order to satisfy the rules.

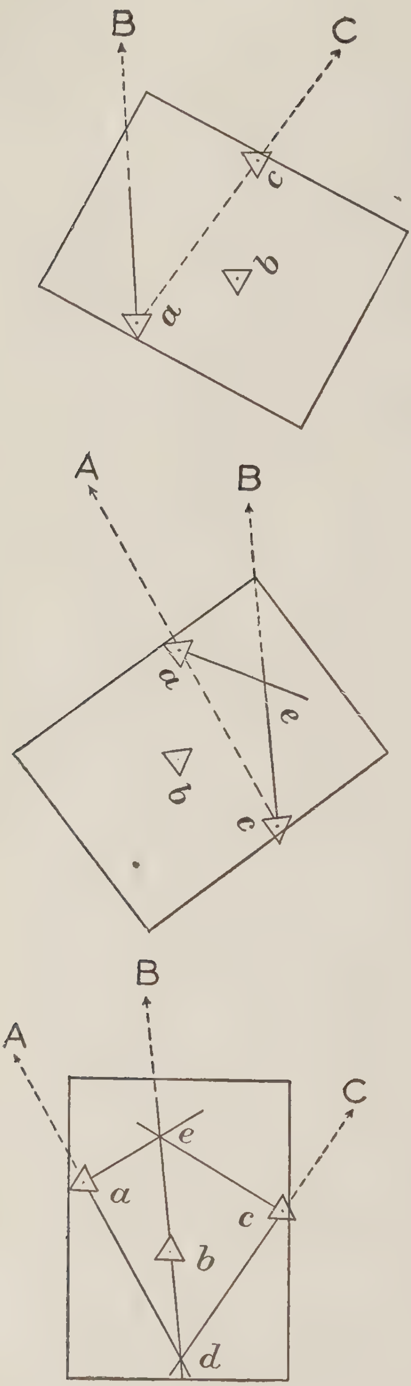

FIG. 15.—Bessel's solution of three-point problem

Conditions illustrated in Figure 14 hold good in all cases; that is, if the table is located outside the triangle formed by the three control stations, its position on the sheet will lie outside the triangle of error; if it is located inside the triangle, its position will lie inside the triangle of error. This is sometimes called Rule III.

The effect of distortion of the sheet on the solution of the three-point problem and the allowances to be made for such distortion are discussed on page 64.

Bessel's method.—The three-point problem can be solved, without the necessity for a triangle of error, by Bessel's method. This method is very satisfactory unless, as frequently happens, the intersection of construction lines falls off the sheet.

This method is illustrated in Figure 15. The capital letters at the ends of arrow lines designate stations on the ground that are used for orienting or to which cuts are taken. The relative location of the stations are shown by their plotted positions, *a*, *b*, and *c*, on the sheet. The location of the unknown point with relation to the three control stations is indicated at *d* in the lower illustration. The procedure is as follows:

Set up and level table over the unknown point. Place alidade so that the edge of the base passes through the plotted points *a* and *c*, with telescope pointing toward *c*. Adjust table until the signal at *C* is bisected by the vertical line of the telescope. Place alidade so

that the edge of the base passes through the point *a* and the signal at *B* is bisected by the vertical line and draw a cut on the sheet along the edge of the base. It will be noted that this procedure is exactly the same as would be the case if the table were actually set up over *A* (instead of the unknown point), oriented on *C*, and a cut taken to *B*. The result will be a cut on the sheet as indicated by the solid line from *a* in the upper illustration.

Next assume that the table is set up over station *C*, orient on *A*, and cut again to *B*. This will give a second cut on the sheet, extending from *c* and intersecting the first cut at point *e*, as indicated in the center illustration.

Now place the alidade so that the edge of the base passes through the points *b* and *e* on the sheet and adjust table so that the signal at *B* is bisected by the vertical line of the telescope. The table is now properly oriented, and a line drawn along the edge of the base (a prolongation of the line *eb*) will give a line of position for the unknown point. Resection on *A* and *C* should give two additional lines intersecting the first line at the same point (*d* in the lower illustration), which is the position of the unknown site over which the table is set up.

The triangle formed by the three plotted points *a*, *b*, and *c* can be contracted or expanded, as may be desirable in order to bring the intersection *e* within the limits of the sheet, by drawing a line parallel to the longest side and terminated by the other two sides. The solution is then made in the same manner as with the original triangle.

Tracing-cloth protractor.—Another solution is obtained by laying off the angles between the three control stations on tracing cloth or paper and using this as a three-arm protractor to determine the position of the unknown point.

Fasten the tracing sheet to the board and mark a point upon it to represent the unknown point. With the edge of the alidade on this point, sight on the known points and draw the three cuts. Release the tracing sheet and shift it over the plane-table sheet until each of the cuts passes through the plotted position of the station to which the cut was taken. The intersection of the three cuts on the tracing sheet is now in the proper position over the plane-table sheet to indicate the position of the point sought. This position must be verified by orienting and resecting on the three control stations.

TWO-POINT PROBLEM

It is sometimes desirable to locate and orient the table at a point from which only two control stations are visible; this may be done in several ways.

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When it is practicable to set up the table in range with the two stations, the position of an unknown point can easily be determined as follows: Set up the table anywhere on the range line and orient by the latter. Place the alidade at any convenient location on the sheet so that a flag or other object, erected over the unknown point, is bisected by the vertical line of the telescope and draw orientation lines along the edge of the base.

Leaving a flag at the first site of the table, proceed to the unknown point, set up the table, reverse the alidade, and orient by a backsight on the first point occupied. As the azimuth of the table is now the same as when on the range line and the table is, therefore, properly oriented, the position of the point sought is shown by the intersection of resection lines from the two control stations.

The solution of the two-point problem, generally used when it is impracticable or undesirable to set up on range, is illustrated in Figure 16. This method requires no linear measurements and demonstrates the effectiveness of the plane table as a surveying instrument. Two cases are illustrated in the figure; the description of the method given below is applicable to both cases as well as to other locations of the points.

In the illustration, a and b are the plotted positions on the sheet of two control stations A and B, not conveniently accessible, from which it is desired to locate and orient the table at an unknown point (call the unknown point C). The procedure is as follows: Select a fourth point (call this point D), where the resection lines from A and B will give a strong intersection. This point also must be so situated with respect to C that cuts on A and B from C and D will give good intersections. Orient as closely as possible, by eye or with the declinatoire, and resect on A and B.

Intersection of the resection lines at d' gives a tentative position of D, differing from its true position because of the error in orientation. Sight on an object erected at C and draw orientation lines and a cut through the point d'. Plot c' on this cut at a distance from d' corresponding to the estimated distance from D to C.

Next, set up the table at C, reverse the alidade on the cut d' c', and orient by a backsight on D. The error in orientation is now the same in extent and direction as at D. Sight on A and draw the cut through c' to intersect the line ad' at a'. Then sight on B and obtain the intersection at b'.

The quadrilateral, $a'b'd'c'$ in case 1, or $a'c'b'd'$ in case 2, has the same shape as that formed by the four points on the ground but is erroneous in size and position. In all cases, however, the line $a'b'$ is parallel to the line AB on the ground so that the error in orientation is indicated by the angle between the line ab and the line $a'b'$.

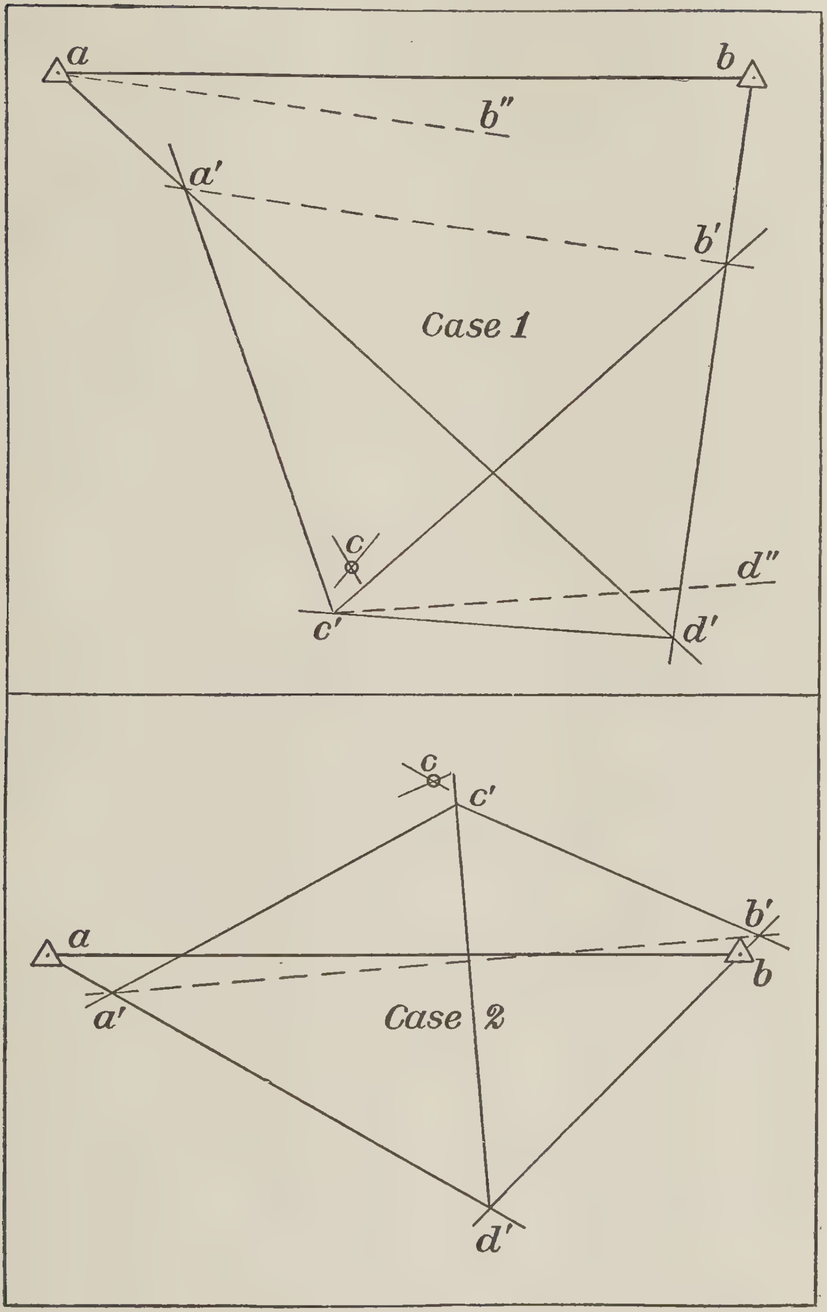

FIG. 16.—Two-point problem

A convenient method of correcting the orientation is to place the alidade on the line $a'b'$ and to note some distinctive and distant object that is bisected by the vertical line of the telescope. Then place the alidade on the line ab and adjust the table until the same object is again bisected. The table is now oriented correctly, so that resection on A and B establishes the true position of the point sought at c.

A second method of correcting the orientation (illustrated in case 1 only) is as follows: Construct the line ab'' parallel to $a'b'$. The error of orientation is given by the angle bab''. Lay off the line $c'd''$ to make the same angle with the line $c'd'$. Note that this angle must be laid off in the opposite direction; that is, if ab'' bears to the right of ab, then $c'd''$ must bear to the left of $c'd'$. Place the alidade on the line $c'd''$ and adjust the table so that D is bisected. This operation orients the table correctly.

Another available method, involving the measurement of a base, is not described, as it is more laborious than the one given above.

DISTORTION

Distortion of a plane-table sheet destroys the perfect proportions that exist between the control stations and their plotted positions. The amount of distortion can be measured at any time by means of the check distances placed on the sheet in accordance with paragraph 7, part 1. The topographer should measure the sheet for distortion from time to time and should take advantage of opportunities, while at control stations, for ascertaining the effect of distortion by pointing to other control stations on the sheet.

The effect of distortion upon the determination of a point is illustrated in Figure 17.

A, B, C, etc., are plotted in their true relations. After the sheet has contracted, a, b, c, etc., represent the relations those points have assumed. The paper contracts at a uniform but different rate in each direction.

The plane table is supposed to be at X, the exact center of the figure, and it is required to determine the position by the distorted points a, b, c, etc. By reversing the telescope, we immediately ascertain that we are directly on the line HD. Reversal will also show that we are on the lines AE, CG, and BF. But the distortion is not apparent until the telescope is pointed at the signals and the lines are drawn on the sheet. Then, if we orient by the line HD, we shall produce the figure of the diagram, giving five determinations, 1, 2, 3, 4, and X, each made with four well-conditioned points. Any one of these conditions would be considered satisfactory if we had not the other points to show that something was wrong. Orient-

ing by the line BF will produce the same result. But if we take the diagonal AE, we shall have two positions at 5 and 7, formed by the intersection of the diagonal points, with the lines from the other points running wild. Using the diagonal CG would give two points at 6 and 8, with the lines from the other points running wild as before.

Position by compromise.—There is no question that out of the nine positions developed by these settings the one at X is the only true compromise. When the sheet is distorted, all positions are compromises; and X is the true compromise in this case, for it is on the lines CG, AE, etc.; a is below and e above the line connecting A and E, by equal quantities. A line drawn through the distorted points a and e must pass through the middle point X. The positions 5, 6, 7, and 8 can not be true, because lines forming them will not pass through the opposite points when extended, which we know to be the condition that must be filled. The following rules apply:

(1) A station established from three points, such as h, b, d, that are on the lines of contraction, the resecting lines forming nearly right angles at their intersection, will give the true position in relation to all points in the sheet.

(2) A similar condition of right-angular intersection at the station, but with the lines forming diagonals to the lines of contraction (using stations a, c, and e, for example), will give the worst possible position for the station.

(3) A station established from three points, such as a, b, and c, on one of the lines of contraction will give the correct orientation of the table but not the correct position.

(4) In estimating errors of the point due to distortion, those situated on the lines of contraction require no allowance, however distant.

Application.—If the change in the sheet due to contraction or expansion gives the same percentage of the units of length, both lengthwise and crosswise of the sheet, the points are still in their true relative positions, and the projection is practically as good as when laid on the paper but is on a slightly altered scale. When the percentage of change in the units of length is greater in one direction than the other, the sheet and projection are distorted; and to locate a station by the three-point problem, allowance must be made for the change of scale in each direction. The difficulty in making such allowances is not great, if the principal effects of distortion in the sheet are borne in mind.

It would not be permissible, even were it practicable, to make new points on the sheet, as this would destroy the geographic position.

It is necessary, therefore, to assume the new points by estimation, applying the percentage of change to the distances measured between the points on the lines of change—that is, on lines parallel to the edges of the sheet. If the point occupied and the point sighted to are on a line parallel, or nearly so, to one edge of the sheet, its movement from the distortion can only be along that line.

When the position of the point sighted is found situated to one side of the line parallel to the edge of the sheet, the distortion will also affect it in the direction at right angles to that edge, and the effect of the distortion will be most apparent when the angle of deflection is 45° and the position is at as great a distance from the

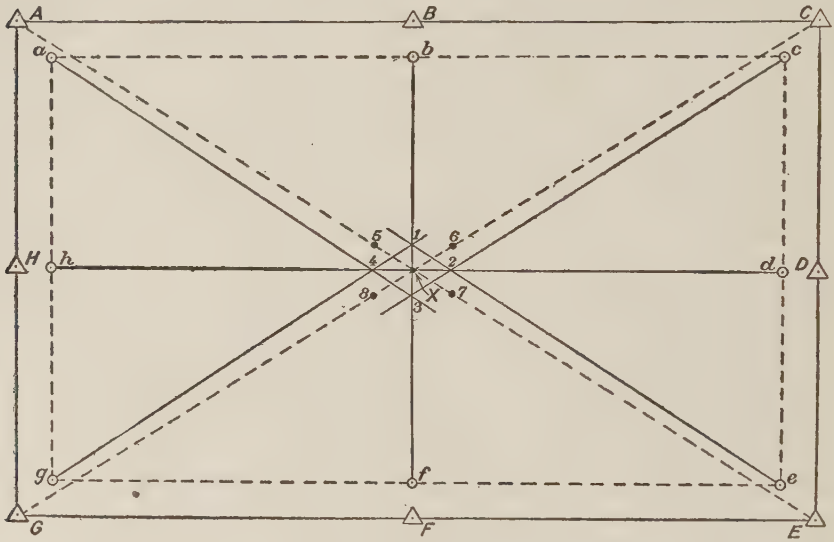

FIG. 17.—Distortion of sheet

point occupied as the paper will permit. As the angle of deflection increases above 45°, the effect becomes less and disappears at 90°, when the position will fall again in a line parallel to an edge of the sheet.

Referring to Figure 17, to establish a station from the three points *a*, *b*, *c*, if the sheet were not distorted, the station would be at *X*—*A*, *B*, and *C* being the true positions plotted when the projection was drawn. But the sheet having contracted, *a*, *b*, and *c* show the relative positions of these points; therefore we make such allowance for the contraction derived from measuring the unit of length that we can place or imagine *a* and *c* to be where they belong, at *A* and *C*; *b* requires no change, as it is on a line parallel to the edge of the sheet. To locate *A* we must know the distances (approximately) *h* to *a* and *h* to *X*, which, multiplied by the percentages of contrac-

tion (in this case), will give the distance of A above and to the left of a. The same process locates C.

If the station were to be established from the points a, c, and e, all three points would have to be imagined in a new position by the same process that A has been located.

Stations made in this way will be good for all local sketching within an area such that the contraction of the sheet is inappreciable; but to take cuts on distant objects from such a station the orientation of the table must be changed. If an object is somewhere near the direction of a and the table at the compromise station X, the table must be oriented by a and X, the imaginary position A being discarded.

The same processes apply to all positions on the sheet for the station occupied.

If a control station is located at some point such as X and it is desired to occupy this station, the distant station used for orienting should, if possible, be selected so that the line of sight is parallel, or nearly so, with an edge of the sheet. In this case no allowance for distortion is necessary.

If necessary to orient on a station such as a, the true position of point A must be estimated as indicated above. In either case the displacement of the plotted positions of other stations must be considered in resecting on such stations. Allowances to be made for stations plotted in other positions on the sheet will be understood from a study of the diagram.

As mentioned above, orientations of this nature will serve for local sketching. For cuts on distant objects the table should, if possible, be oriented on the plotted position of a station in the direction of the cut.

The methods outlined in this section should be considered only as means for making the best of a bad situation. Work on a badly distorted sheet is unsatisfactory and every effort should be made, by thorough seasoning of sheets and by careful handling thereafter, to avoid conditions that will cause abnormal distortion.

DELINEATION OF TOPOGRAPHIC FEATURES

At each plane-table set-up the topographic features in the vicinity of the station should be mapped in accordance with paragraph 16, part 1. Such features may be located by cuts and rod readings from the station or by cuts from two or more stations, depending on conditions.

Among the features usually located by rod readings are the high-water line, small streams, buildings and similar objects along shore, limits of various kinds of vegetation, etc. For such readings it is

not necessary to draw the cut lines. The distance can be set on the dividers and pricked along the edge of the alidade base.

The proper delineation of the high-water line is, of course, very important, and the rodmen should be trained to give a sufficient number of properly spaced readings so that the shore line can be drawn correctly. The head rodman usually gives the shore-line readings on his way to the next set-up point while the rear rodman gives readings on other features.

A rod reading at a building, wharf, or similar feature can usually be identified by the topographer, but there is likely to be some uncertainty concerning rod readings along the high-water line. For this reason a simple signaling system for shore-line readings is often valuable. Thus, after the rod reading, the rodman might hold the rod at an angle of 45° with the top pointing offshore to indicate a reading on a projecting point; at the same angle, but with the top pointing inshore, for a reading at the head of a small indentation; horizontal above his head for a reading at the mouth of a small stream; etc.

It will be of great assistance to the topographer if the rodmen can be taught to sketch the topography near each rod reading, using a sketchbook and numbering each rod reading.

The topographer may draw in the high-water line very lightly as the readings are given and then, at the next set-up, correct the original drawing from information obtained while traveling along the shore between the two stations or from the rodman's sketches. Any additional readings that are considered necessary can be given by the rear rodman. (See also "determination of high-water line," below.)

Objects located by cuts may include off-lying objects such as rocks, breakers, aids to navigation, etc.; mountain peaks and other prominent elevations (measurement of elevations is discussed in a later section); limits of vegetation at a distance; and the upper tree line on mountains. (Distinctive points of woods or dead trees along the latter can often be located by cuts.) Direction lines to prominent features that do not come within the limits of the sheet are often desirable.

The nature of the shore and all features, as they are located, should be shown on the sheet by symbols or by limiting lines and legends. Standard symbols are given on pages 104 to 113. Sections of topographic sheets on which the symbols are used are reproduced on pages 115 to 117.

The sheet section shown on page 115 illustrates the use of rock symbols as prescribed in paragraphs 37 to 39, part 1. Generally foul ground, the limits of which are unknown, off a point on the

westerly shore is indicated by three sunken-rock symbols. Two rocks awash and one sunken rock off the northwest point were definitely located and are therefore surrounded by dotted lines. A short distance to the eastward the limits and nature of a sunken reef off the point as shown by a broken line inclosing rock symbols. The outermost sunken rock, however, was definitely located and is encircled by a dotted line. Still farther eastward sunken-rock symbols are used to indicate foul ground between two islets but not the definite number or location of the rocks.

Preliminary locations.—In case a feature to which a cut is taken will be difficult to identify from other stations, an approximate position can be obtained by measuring a vertical angle and computing the distance, or by observing another cut from a near-by station. Such locations, of course, will have no value except to indicate the approximate direction for sighting from other stations that are suitable for obtaining good intersections of cuts.

Determination of high-water line.—The mean high-water line, considered to be the shore line in the topographic work of the Coast and Geodetic Survey, is seldom well defined. The topographer should familiarize himself with the tidal characteristics of the region under survey, so that he can ascertain his location relative to mean high water at any time by measuring to the surface of the water. Times of high and low tide can usually be obtained from the tide tables, which also give a method for obtaining the predicted height of tide at any time.[4] A method of computing the high-water plane is given on page 75.

Where the beach slopes gently and the tidal range is large, it is practically impossible to identify exactly the mean high-water line. In this case the topographer should note the characteristics of the shore at mean high water. On a sand beach there may be a difference in the size of the sand or its compactness, as the sand back of the high-water line is usually coarser and less compact. Mud flats may have a different color or a difference in the character of the sun cracks; there may be tufts of grass or other vegetation along the high-water line.

The mean high-water line must not be confused with the storm high-water line, which is usually marked by driftwood and the edge of considerable vegetation. (See also pars. 30 and 43, pt. 1.)

HYDROGRAPHIC INFORMATION

When topography is carried on as a part of combined operations including hydrographic work, there should be close cooperation

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[4] A method of constructing a predicted tide curve and tabulating the height of tide at any desired interval is described in the Hydrographic Manual of the Coast and Geodetic Survey.

between the topographer and the hydrographer. In many regions one of the duties of the topographer is to construct and locate small signals at suitable intervals along the beach for use in extending hydrographic work close inshore.

Such signals should be varied as much as possible, to avoid confusion. They may consist of whitewashed rocks, cloth banners on bushes, flags, slats on trees, etc. For this work the topographer should be familiar with the principles involved in controlling hydrographic work, as given in the Hydrographic Manual of the Coast and Goedetic Survey, and should consult with the hydrographer relative to his requirements for signals in the locality under survey. Short descriptions of the various signals should be noted on the sheet or in a notebook.

Natural or artificial objects along the shore, or in plain sight from the water, such as fence ends, rocks, prominent houses, etc., should be determined and marked upon the sheet.

Lines to buoys and other prominent floating objects at anchor should be, as far as practicable, taken at the same stage of the tide or direction of current.

The mean low-water line should be delineated, but when it is beyond the reach of the plane table and presents no marked points for determination, or is of a character that will not permit the use of the instrument (as along the swampy shores in the South, where the muddy shoals are of great extent, and among the shifting quicksands of our great estuaries and bays), it may be left to be traced by the work of the hydrographic parties. The channels through mud flats of this character should be indicated, however, if only approximately, by cuts and tangents, or the determination of stakes at the turning points. Where the fall of the tide exposes rocks and ledges, shingle beaches, etc., their character and extent should be indicated and distinguished from the sandy beaches, as these features are most difficult and laborious for the hydrographic survey to represent.

In some cases, when a section of the coast has been surveyed at high tide, it may be necessary to return at low tide for the delineation of additional features. If this is likely to be necessary, the plane-table set-ups should be marked so that they can be recovered within a reasonable period.

LANDMARKS

Special attention must be paid to the location of objects which are prominent landmarks. When placed upon the published charts with brief descriptive legends, they are little less than indispensable for the following:

(*a*) Coastwise navigation, especially at difficult entrances or those subject to frequent and considerable changes.

(*b*) Assisting the aerial navigator to recognize and determine his position.

(*c*) As recognizable and controlling points in a photographic survey.

(*d*) The original location and determination of aids to navigation and subsequent verification of their positions.

(*e*) Hydrographic examination of features subject to change, to serve as the basis for more complete surveys, such as entrance approaches, bars, and channels. Also, the verification of reported shoals or other features incorrectly or incompletely charted.

Prominent landmarks are topographic features, either artificial or natural, which are easily distinguished from the surrounding features. They should be comparatively permanent. They include mountain peaks having some unusual feature such as height, color, shape, or appearance; conspicuous cliffs; landslides, bare or having distinctive vegetation; waterfalls; prominent trees; church spires; stacks; towers; and conspicuous buildings.

Features of particular value as control points for aerial photographs are crossroads, railroad junctions, and points at the confluence of streams, ditches, or canals.

A proper note must be made on the sheet and in the descriptive report regarding each. They should be given a name in order to identify them properly when referring to them in the Coast Pilot or when they are seen on the chart. If the number of prominent features located in any one locality is greater than can be shown on the chart, the list should show which are the more prominent or important, so that the chart compiler can make the proper selection.

REPRESENTATION OF RELIEF

There are various methods of representing on maps the relief of a region, such as by hachures or hill shading, contours, form lines, and hypsometric tints. Only the first three are used by the Coast and Geodetic Survey.

Hachures.—Hachures are a system of short lines drawn in the direction of the slope. For a steep slope they are heavy and closely spaced, and for a gentle one fine and widely spaced. Hachures give a good idea of the shape of the ground but do not give the actual elevation above the datum plane. Only relative heights or steepness of grades are indicated.

On a map depicting gentle slopes over its general area it will be necessary to use heavy and closely spaced lines to bring out a slope steeper than the average, while on a map of mountainous area the

same degree of slope would be represented by light hachures, in order to use the closely spaced lines for the steeper slopes. Another objection to hachures is that they cover up other topographic detail.

The Coast and Geodetic Survey uses hachures only to show cliffs, or very steep slopes where contours run together, and bluffs along the shore, especially when the height of the latter is less than the contour interval.

An illustration of the last-mentioned use of hachures is given in Figure 18, representing a short section of coast line. Reading the hachures from left to right, we see first a fairly steep bluff along the shore, which after a short distance leaves the beach and extends inland along a small stream. On the other side of the stream a low bluff

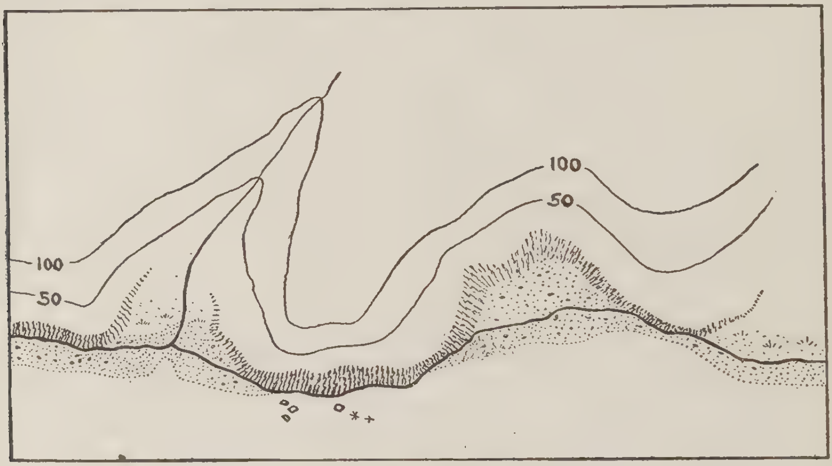

FIG. 18.—Hatchures

starts. It extends down to and along a rounding point, becoming higher and more precipitous. Just beyond the point it becomes lower but remains steep, and then recedes inland, leaving a small area of beach. Here it is quite high but not so steep. Extending down to the shore again, the bluff becomes lower and steeper and finally disappears inland.

Contours.—A contour is a line that passes through points having the same elevation above a datum plane; that is, a line that would be formed by the intersection of a horizontal plane with the surface of the ground. It may also be described as an imaginary shore line that would be formed were the water to rise to the height represented by the contour.

A contour system is a series of contours separated from each other by a constant vertical interval. As the contours must be delineated in their true positions with relation to each other and to the rest of

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FIG. 19. – SKETCH OF BAY WITH SURROUNDING HILLS AND GRANITE CLIFF

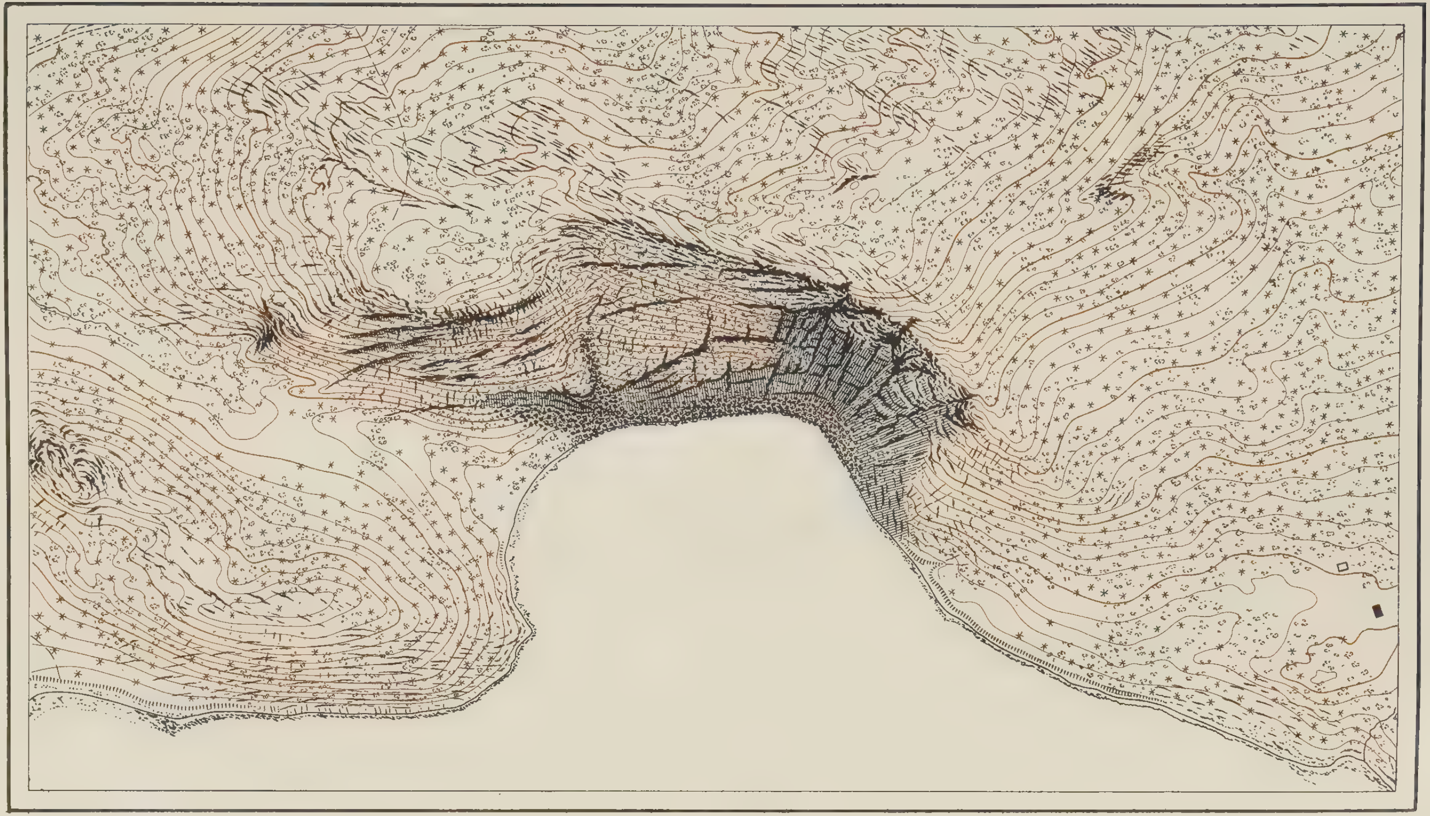

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FIG. 20. – TOPOGRAPHIC MAP OF LOCALITY SKETCHED IN FIGURE 19.

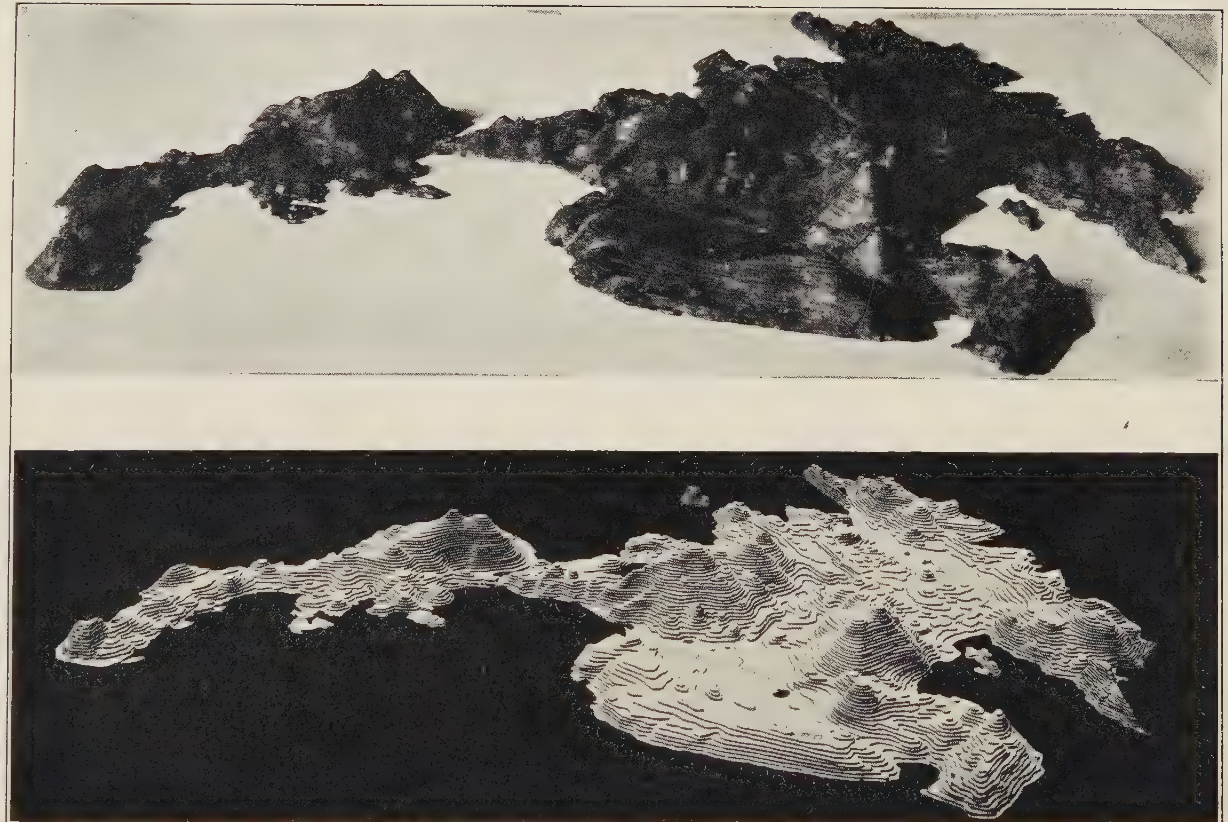

FIG. 21.—RELIEF MAP

the map, they show not only the various elevations of the region mapped but also the shapes of the hills, valleys, etc. The amount of slope is indicated by the distance apart of the contours on the sheet. Relatively far apart for gentle slopes, the distance between successive contours decreases as the slope becomes steeper, until they may run together to indicate a vertical cliff.

The use of contours may be understood by reference to Figures 19, 20, and 21. Figure 19 represents a small bay with adjacent hills and a granite cliff near the shore. Figure 20 illustrates a topographic map of the same area.

Figure 21 illustrates the manner in which a relief map might be constructed from the information given by the contours of a topographic map. In the lower part of the figure, layers of cardboard are cut to conform in shape with the configuration of successive contours and are superimposed in the proper relative positions of the various contours.

If this base is now covered with some plastic material so that curves and slopes are even and regular, and the upper edge of each cardboard layer is flush with the surface of the material, the result will be a relief map (upper part of figure) the accuracy of which corresponds to that of the topographic map.

In order to assist in reading contours, every fifth one is accentuated by a heavier line and is numbered at frequent intervals along its length.

When a contour runs very near to some remarkable relief feature, as a prominent spur or indentation, but does not indicate it, a slight deviation above or below the plane, in order to include the feature, is permissible.

Typical contour groups are shown in Figure 22. The arrows are inserted to show the direction of the drainage but are not used in actual mapping. Two groups showing erroneous contours are also given.

A closed contour encircled by one or more closed contours is either a hill as shown in case 1 or a depression, such as a dried lake, as in case 2. If it is a depression, hachures on the down-slope side and contour numbers indicate the fact. Case 3 illustrates the representation of a ridge by contours. The same system of contour having the arrows reversed would represent a ravine. Case 4 shows a saddle between two hills. Case 7 illustrates the junction of mountain streams.

A contour never splits, as shown in case 5; nor do two contours run into one, as shown in case 6; nor cross each other except in the rare instance of an overhanging cliff, as shown in case 8. A contour can not have an end within the map; it must either close on itself or commence and end at edges of the sheet.

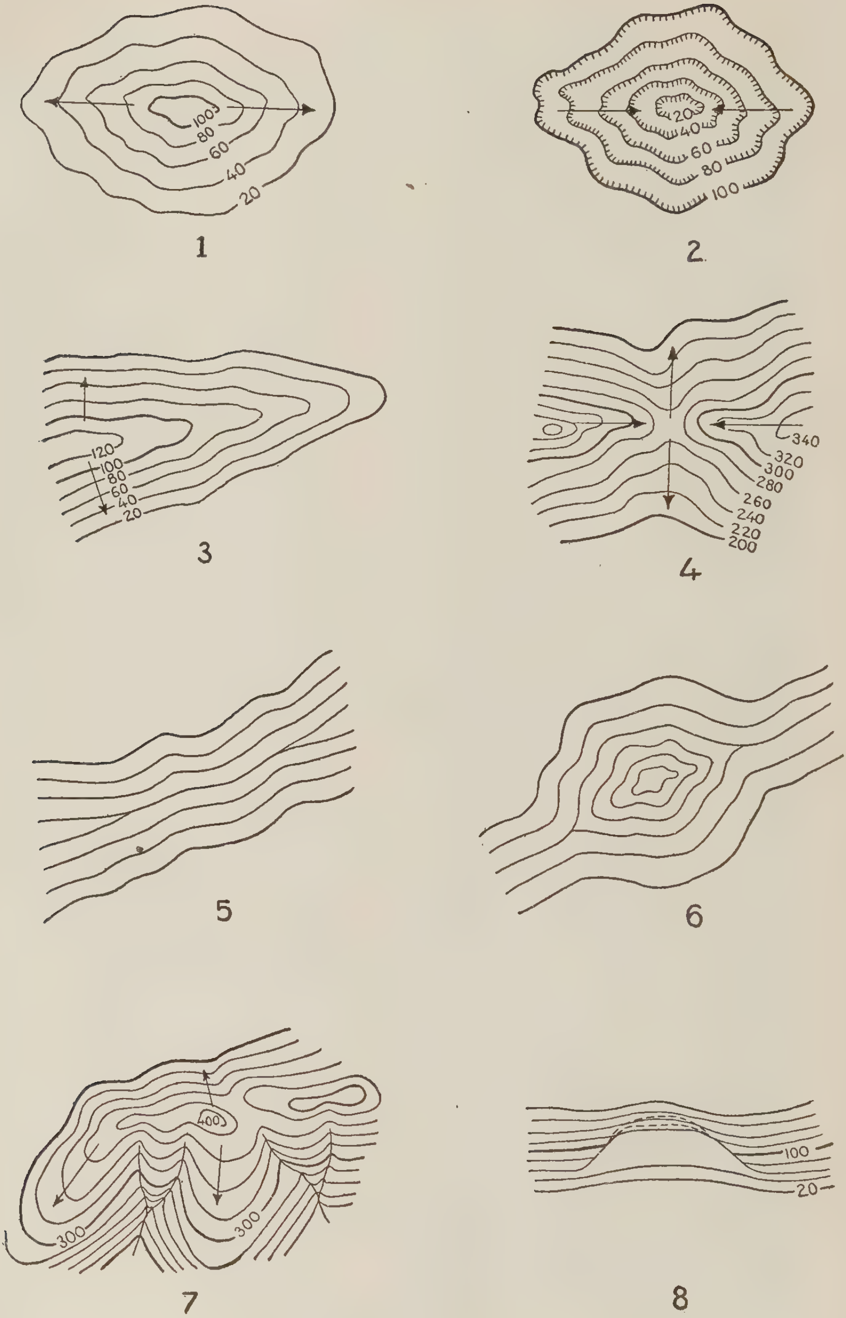

FIG. 22.—Contour groups

Contours give a maximum amount of information without obscuring other detail and are used by the Coast and Geodetic Survey for mapping all regions except Alaska and the Philippine Islands. They are sometimes used in combination with hachures, as indicated above.

Form lines.—Form lines resemble contours but are not drawn with the same degree of accuracy. They show the general configuration of the country so as to make it recognizable. Each line represents a definite elevation and is controlled by as many determined heights as it is practical to secure, but not a sufficient number to conform to the standard of accuracy usually required for contours.

The Coast and Geodetic Survey has prescribed the use of form lines for indicating the relief in Alaska and the Philippine Islands. This is because the standard of accuracy required for contours is not practicable. As it is important for the benefit of the navigator to include a large area of rugged country back from the shore, its general configuration must be indicated and the peaks and hilltops charted to serve as landmarks. The representation of relief of this nature by form lines is sufficient to meet the needs of navigation, so that the great amount of time and expense required for contouring would not be warranted.

Contour and form-line intervals.—The general requirements are given in paragraph 23, part 1. Selection of an interval from those prescribed depends chiefly on the nature of the country to be mapped. The shorter intervals will generally be used in regions where slopes are gentle and elevations moderate.

Hypsometric tints.—In hypsometric tinting, or the layer system of coloring, a scale of gradually shaded tints is used to aid in the reading of contours. The area lying between two selected contours is colored one tint and that between two others another tint, etc.

Where there are not too many contours, a different tint is used for the area between each successive pair; but where there is a wide range of elevation, it is necessary to use each tint for an interval of several contours.

The Coast and Geodetic Survey does not use this system, as the information required by the navigator can be shown with less expense by contours, or form lines, and hachures.

Datum plane.—The datum plane for elevations adopted by the Coast and Geodetic Survey for topographic work is mean high water. The mean high-water line which is considered to be the shore line is, therefore, the zero contour.

The zero contour may be determined with sufficient precision for topographic work by reference to the surface of the sea as follows: Note the time and determine the height of the tide at that time from

the tide tables. For the Atlantic coast the high-water plane above the water surface may then be readily determined by subtracting the height of tide from the mean range of tide. On the Pacific coast the high-water plane above the water surface may be determined from the formula

$$\text{HW plane} = (D + \tfrac{1}{2}\,Mn) + \textit{ht. diff.} - \textit{ht. of tide}$$

in which D represents the depression of the datum below mean sea level at the reference station (p. 9 of tide tables), Mn, the mean range at the reference station; *ht. diff.*, the height difference given in Table 2 of the tide tables, applied algebraically, and *ht. of tide*, the height of the local tide as determined above. If the resulting sign is plus, the high-water datum is that amount above the water surface, while if the sign is minus the high-water datum is that amount below the water surface.

All elevations are of the ground; therefore, the height of trees obscuring the ground must be estimated and a note of this estimate made on the sheet near the elevation. There must be no uncertainty, whether the elevation given is to the ground or tree tops.

DIFFERENCES OF ELEVATION

In order that the relief of a region may be shown by contours, or form lines, and hachures, the elevations of a sufficient number of points must be obtained, over the region under survey, to enable the topographer properly to delineate the lines on the sheet. The number of elevations required for the delineation of contours with the accuracy prescribed in paragraph 20, part 1, will depend on the nature of the country and the skill of the topographer.

Elevations required for form lines are specified in paragraph 21, part 1. As indicated in this paragraph, the requirement of one elevation for every 4 square inches of sheet should be considered the minimum, a larger number being very desirable.

The topographer should take advantage of every opportunity, during the course of his work, to determine the elevation of points. Some of the most useful methods are given below, the first two being the ones most used by the Coast and Geodetic Survey:

1. Vertical angles measured with the alidade, the distance from the table being obtained by rod readings or by intersecting cuts.
2. The degree of slope measured and the corresponding horizontal distance between the contours, as determined by tables, stepped off on the lines drawn to represent the direction of the slope.
3. Elevations determined by aneroid barometer.
4. Lines of levels run across the area to be surveyed and additional elevations determined by stadia and vertical-angle traverses.
5. Elevations determined by the use of the hand level.

6. Following each contour by running a traverse, keeping the instrument at a constant elevation.

7. Dividing the area into regular divisions, as quadrilaterals, driving pegs at each corner, and then determining the elevation of each peg by levels.

Vertical angles.—To measure vertical angles, have the plane-table level and the alidade striding level in adjustment. Point on the object, move the telescope until the object is brought on the central horizontal cross hair, and read the angle on the vertical circle of the alidade. Without moving the alidade or table, raise or lower the telescope until the striding level indicates that the telescope is level. Read the vertical circle. The latter reading is the index correction which must be applied in the proper direction to the first angle.

The center horizontal cross hair should be checked for adjustment several times during the day (see p. 17). A more accurate determination of the index correction can be obtained by reversing the stride level, reading the vertical circle again with telescope level, and taking the mean of the two readings. As it is difficult to keep the stride level adjusted, and as the two readings require only a short time, this procedure may be used to advantage for all vertical-angle readings.

When it is necessary to carry the elevation of the table from station to station, as when running a traverse away from the shore, the procedure of reversing the level and revolving the telescope for each reading, as described on page 18, should be followed. In all cases the alidade may be placed at any convenient location on the sheet for observing vertical angles and reading the vertical circle.

Whenever practicable, elevations should be checked by a second vertical angle from another plane-table set-up.

Distances between the table and objects located by cuts are scaled from the sheet; distances by rod readings must be reduced to the horizontal. When the rod is held vertical, as is usually the case, a second correction for the oblique view of the rod must also be applied. Tables are given in the appendix for making these corrections; also a table to be used when the rod is held perpendicular to the line of sight.

To secure the latter condition, a pointer perpendicular to the rod, arranged on a slide so that it can be adjusted to the height of the telescope, should be provided. The rodman then holds the rod so that the pointer is aimed at the instrument.

Stadia tables can be prepared for obtaining the difference of elevation directly from an inclined sight.

Vertical angles to objects at a distance must be corrected for curvature of the earth and refraction. The correction for curvature is about 7 inches for 1 mile and increases approximately as the square

of the distance in miles (see fig. 23). Corrections for curvature and refraction are given in tables in the appendix.

Differences of elevation can be computed by means of the hypsograph (see p. 20) or by use of tables given in the appendix. If neither is available, the following simple formula may be used:

Formula for determining heights by a vertical angle and distance.—The difference of level consists of two parts—that which arises from the angle of elevation above the horizontal plane of the station and that which is due to the curvature of the earth. The former depends upon the angle and distance, the latter upon the distance and the earth's radius. If a' be the angle of elevation in minutes of arc, d the distance, h, the height, then, as the tangent of 1′ is $\frac{1}{3438}$, we have for the first part $h=\frac{1}{3438}a'd$, if h and d are both expressed in the same units of length, but if d is expressed in meters and h in feet, 1 meter being 3.28 feet, we get $h=\frac{1}{1048}a'd$. For the fraction $\frac{1}{1048}$ we may conveniently and with sufficient accuracy put $\frac{1}{1000}$ less $\frac{1}{20}$ of $\frac{1}{1000}$, and thus find the rule: *Multiply the distance in meters by the number of minutes of arc, point off the thousandth part, and subtract*

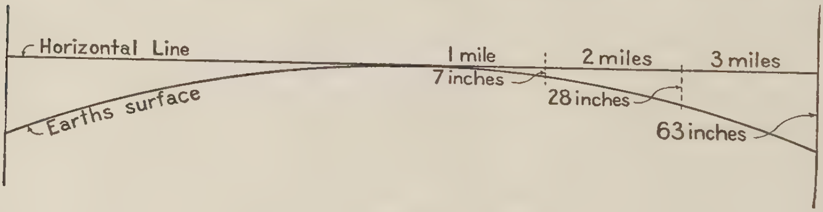

FIG. 23.—Curvature of earth

the twentieth part of the number thus obtained. This will give the first portion of difference of height, whether elevation or depression.

The second term, depending on the curvature, varies as the square of the distance and amounts to 0.22 foot in 1,000 meters, including the effect of ordinary refraction. As with the instruments under consideration extreme accuracy is not attainable, this term may be neglected for distances under 1,000 meters. When the distance is greater, we have the following rule: *Take the thousandth part of the distance in meters, square the same, having regard to the first decimal figure, and multiply by 0.22.* This term is always positive. If the first term be an elevation, it is increased; if a depression, it is diminished by the second term.

Example: Distance=5,500 meters; angle of elevation, 36′.

$\frac{1}{1000}d\times a'$	=198.000	$\frac{1}{1000}d$	= 5.5
subtract $\frac{1}{20}$	9.9	square	=30.2
		multiply by	0.22
first term	188.1		
second term	6.6	second term	6.64
sum	194.7=difference of elevation in feet.		

Height of telescope.—The height of the telescope above the datum plane must ordinarily be applied in the proper direction to the differences of elevation. When sighting on a rod, however, the height of the telescope above the ground may be eliminated by providing a marker on the rod, to be adjusted to the height of the telescope above the ground, and sighting on this marker. For ordinary topographic work it is sufficiently accurate to estimate the proper point on the rod, being guided by the height of the rodman. In this manner the elevation of the ground, instead of the height of instrument, is carried.

Step method.—The step method of determining difference of elevation consists of noting the intercept on a stadia rod of two of the stadia wires and then, in the case of a higher elevation than the instrument, lowering the telescope by successive steps, at each step placing the upper wire where the lower one was formerly, until the telescope is level. The number of steps multiplied by the stadia intercept, plus or minus the height of the wire on the rod, gives the difference of elevation. The various parts of a tree or points on a hillside are used for the stepping of the wires.

This method is used very little by the Coast and Geodetic Survey, because it is easier to read the distance and vertical angle and compute the elevation with the hypsograph. Moreover, the stadia rods are not graduated for this purpose. It is sometimes useful, however, for approximating the elevation by estimating the amount of intercept of the wires on a tree, house, or similar object, at the desired distant point. This value, when stepped down, gives an approximate difference of elevation.

Aneroid barometer.—The aneroid barometer is used only occasionally by the Coast and Geodetic Survey but is a useful instrument for measuring elevations in rough topographic surveys away from the coast. This instrument is a barometer with a circular dial graduated to read elevations in accordance with the principle that the barometric pressure is different at different elevations. A change in the atmospheric conditions, however, will indicate on the instrument a change in elevation, although the barometer is not moved in elevation. For this reason the aneroid must be set at the correct elevation at a station whose elevation is known in accordance with the existing atmospheric condition at the beginning of the day's work and again compared at the end of the day, as well as several times during the day, and the readings taken between comparisons corrected.

If it is impossible to compare the aneroid barometer during the day, hourly readings can be taken on a stationary barometer by some one left in camp and the aneroid readings later corrected in

accordance with these hourly observations. This might result in considerable adjustment of contouring which was done during the day.

Hand level.—The hand level is sometimes used, but not often. It is a small, short telescope of low magnifying power fitted with cross hairs and a horizontal level that can be seen when looking through the telescope. In going upgrade, the observer sights at some object which the bubble shows to be on a level with his eye, walks to that point, sights on another object equal to the elevation of his eye, moves to that place, and so on. The final elevation is the height of his eye above ground multiplied by the number of sights.

For going downhill, the observer points on the place where he stood previously—the reverse of the rising-elevation method.

CONTOURING AND FORM LINING

The representation of relief by contours or other methods should be done in the field, where the features can be seen. The practice of obtaining elevations, drawing only a few master lines, and then completing the contouring or form lining in the office should never be followed, as it will lead invariably to gross errors. The value of the plane table depends upon all features being mapped while visible.

Topographic forms.—In order to carry on his work successfully the topographer should know something about the geologic structures composing the earth's surface—the way in which the various rocks have been upheaved, eroded, folded, or deposited—as well as the various methods of showing the relief. Without this knowledge he is unable to see topographic forms in their proper shapes and proportions and reproduce them on the map faithfully. He must know what to look for in order to visualize properly. Knowing how the features were formed by nature enables him to generalize better. His duty is to select the most significant features and omit unimportant details. It is not merely a question of representing the biggest things and omitting the small ones. If he is not careful, his map may be indefinite or expressionless. The contours may be too rounded and sweeping or too sharp and angular.

In general, a country of recent geologic age, called a new country, will have cliffs, steep slopes, sharp ridges, narrow valleys, and high summits, especially if composed of hard rock. The contours will be close together and the angles comparatively sharp. An old country will have been eroded so that the hill or mountain tops will be rounded, the slopes gentle, stream beds wide and with a small gradient, and much deposit at the base of the hills. The country will be

rolling. Hence, the contours will be rounding and have few sharp turns.

Contouring.—Every effort should be made to draw in the contours so that an accurate and comprehensive representation of the relief is given. It is best to work from a summit downward, but this is usually impracticable in the work of the Coast and Geodetic Survey, as the topography is mostly along the coast.

The general drainage system should be studied, as this knowledge is of material assistance in estimating the master lines. It should be noted that great differences of elevation give short, narrow valleys and ridges and steep slopes; that swift streams usually have straight channels and slow streams crooked channels.

As a basis for contouring, the topographer, at each plane-table set-up, should sketch in the ridge and valley lines that can be seen, showing the main and subordinate summits, saddles, junction of ridges, and the starting points and junctions of drainage channels. This sketch may be corrected from time to time as additional information is secured.

A definite system of showing such lines, as a two dot and one dash line for ridges and a dot and dash line for valley lines, should be adopted.

It is often desirable to draw a rough form-line sketch to show the estimated position of each multiple of the 500-foot contour, or to show some decided change in slope, an unusual feature, or the relation to the ridge or valley line of a recognizable object, such as a rock, bush, or dead tree, to which a cut has been taken. By estimating the distance or elevation of an object sighted on, the corresponding elevation or distance can be determined by computation, using the vertical angle. The comparison of the relative position of points will often assist in estimating heights and distances.

When occupying a control station at an elevation, the topographer should take advantage of the opportunity to sketch in the surrounding territory, cutting to various features and estimating distances or relative elevations by means of vertical angles.

When the alidade is set up at the foot or head of a slope it may be adjusted to parallel the slope and the vertical angle read. By entering the tables with the vertical angle, the horizontal distance between contours along the slope can be determined and plotted.

It is a decided help in contouring if an elevation is determined on a valley line equal to one on a ridge. This fixes the position of the same contour on the ridge and in the valley. The other contours can then be drawn with the proper degree of parallelism to the first contour.

The topographer should train his eye to judge elevations and distances by making mental estimates before determining the correct

elevation or distance. Caution must be exercised to avoid foreshortening when looking over water, or with the sun at the back of the observer, or with the object in a bright light, as under these conditions the objects look nearer than is actually the case. The contrary is true over undulating ground or uphill.

A false idea of a mountainous country must not be given by showing on the sheet only detached summits of a ridge. The ridge line should be dotted in and the appropriate note given, or it should be indicated by the symbol for form lines of no definite interval (see p. 108).

Form lining.—The process of form lining is the same as contouring except that, as fewer elevations are obtained, more estimating is necessary. As the experience of the topographer and the number of determined elevations increase, the accuracy of form lines approaches that of contours.

In many regions where form lines are used the area along the shore is so steep and mountainous that it is difficult to determine the required number of elevations or to find set-up points from which the locality can be viewed. A valuable procedure in such cases is to obtain the required data from a ship or launch located some distance offshore.

This method, which is described below, is also valuable for verifying form lines or contours that have been delineated from shore stations, since the topographer has the same viewpoints as the mariner who will use the features for the navigation of his ship.

After the topographer has obtained as much information as practicable from shore stations, he proceeds to a suitable position offshore where the vessel stops. The position of the vessel is determined by sextant angles between three control objects on shore and plotted on the topographic sheet (usually protected by a covering of tracing paper or cloth) by means of a three-arm protractor. Angles are then measured with a sextant between one of the control stations and the various features—hilltops, changes in ridge lines, and the like—that are to be located.

The vertical angle between the summit of the feature and the water line directly under the point is measured in each case with a sextant. All angles should be recorded and the cuts plotted on the sheet.

The ship then proceeds to a new position, where sextant cuts to the features sighted at the first position and to additional points are taken and plotted. This procedure is repeated at successive positions until all features to be mapped have been located by three intersecting cuts.

Elevations are computed from the distances scaled from the sheet and the vertical angles, the latter being corrected, by means of the

tables in the appendix, for (1) the height of the observer's eye, (2) refraction, (3) curvature of the earth, and (4) the angle of depression of the shoreline below the horizon.

At each position the topographer sketches the ridges, valley lines, etc., in the same manner as at shore stations and, as soon as sufficient information is obtained, draws in the form lines.

There should be no appreciable change in the vessel's position while the position angles and cuts are being obtained at a station. If there is any wind or current, it may be necessary to take a position for each cut or to use several observers who will observe the position angles and the cuts to various features simultaneously.

AUXILIARY METHODS

Under certain conditions there are various methods that can be used to supplement the plane table in topographic work. The most useful of these methods are described below.

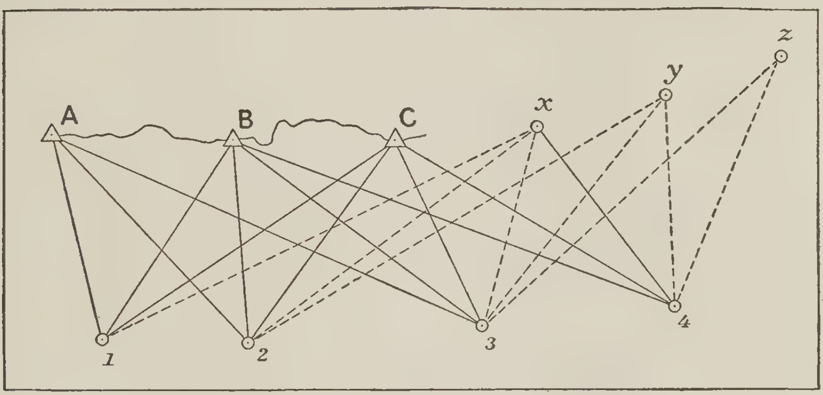

FIG. 24.—Survey of shore line with sextant

Inaccessible shore line.—When it is impossible to land on the shore or to travel along it, or to reach from a control station an area between cliffs, the following method can be used to obtain the topography of the shore line (see fig. 24):

From a boat offshore near the edge of the mapped portion obtain position No. 1 of the boat by measuring with the sextant the two angles between three stations (A, B, and C) whose positions are known. Take angles with the sextant from one of these stations to points or recognizable objects along the shore to be mapped, as x and y. Move to a new location, No. 2, determine the boat's position, and take cuts to the same objects as before and additional ones farther ahead. Repeat at a third station. This gives an intersection by three cuts to some of the points and consequently locates them. Now

the process can be continued by using as known points the position of the objects just located to determine the position of the boat. Sketch in the shore line between the points located.

Carrying auxiliary traverse.—Where an unimportant traverse is to be run, the foresights are short, and only a moderate degree of accuracy is required—such as running out a trail, a small stream, a traverse to obtain elevations, etc.—any of the following methods may be used. In all cases where the topographic features are not drawn in the field but notes taken for their determination, the notes should be accompanied by sketches and the features plotted on the sheet at the first opportunity while the facts are fresh in the mind of the topographer.

Skip set-ups; orienting with the declinatoire.—Set up at B where a known point A can be seen. Orient the table with the declinatoire and resect on A. Draw a short line along the edge of the alidade at the estimated position of the table. Read the stadia distance to A. With this distance, plot the position B of the table on the line drawn. Take and plot a foresight to C. Move the table to a point D beyond C, but where C can be seen. Orient with the declinatoire and read the distance back to C and continue as before.

Compass and pacing.—The azimuth may be carried by a prismatic compass, and the distance by pacing, courses and distances being recorded in a notebook and plotted later. A sketch is drawn of the traverse as progress is made. Care must be taken to indicate whether the azimuth reads from the south or north as zero.

Standardize the pace by walking over a known distance between two located points on level ground and on a slope. Do not try to step a certain distance but walk naturally. Count every fourth step—that is, every other step of either foot. This is much easier and less apt to cause mistakes than counting every step as the slow rhythm is a decided help in keeping the count. A few trials will soon tell the pacer just how many steps he takes for a hundred meters on level ground and how many in going down or up a grade. If 100 paces equals 80 meters on level ground and uphill only 60 meters, then to reduce the count when going uphill to that of level ground, skip the count of one set after every third count of a set of four steps.

Likewise, get the comparison of pace going downhill to that on level ground. Then by dropping or adding one every third, fourth, or fifth count as required, the pacer can walk uphill, downhill, and on level ground intermittently, and when he reaches his destination, reduce his count to meters as if he had been going over level ground continuously.

When using this method of prismatic compass and pacing, stand at a known point, sight with the prismatic compass to some point

ahead, note the reading of the compass, and pace to the point. Repeat to successive points until a tie can be secured on the main traverse or control. Adjust as explained under adjustment of traverse. This method is especially adapted to securing an indefinite shore line back of a mangrove swamp.

Prismatic compass sextant and stadia.—Where it is impossible to walk or set up the plane table, such as in running out lanes or channels in mangroves, three methods can be used. In each case a sketch must be made as the traverse progresses, stations numbered, notes taken and plotted on the sheet in the office.

(*a*) Lay the board across the stern of a small boat. Rest the alidade on this board and, everybody in the boat being perfectly quiet, read the distance on the stadia. Carry the azimuth by prismatic compass. The rodman goes ahead in a second boat and at each turning of the channel gives a rod reading, marking the point by breaking off a branch or tying a strip of cloth on a branch. The topographer follows, stopping at each point just quitted by the rodman.

(*b*) The same as in (*a*), except that the tripod legs are lashed to a pole. The pole is stuck in the mud, thus supporting the table on which the alidade is placed to read the stadia distance. Sometimes the azimuth also can be carried with the alidade as in regular work.

(*c*) Measure a length of 9.544 feet on a rod. This will subtend 100′ of arc at a distance of 100 meters. Then the number of minutes subtended by this length on the rod is inversely proportional to the distance of the rod from the observer. The subtending angle is measured with a sextant. The azimuth is carried by prismatic compass.

The rodman goes ahead of the topographer in a boat. At the turning point selected he holds up (horizontally) the rod on which the above length has been indicated by paint or bands of cloth. The topographer from his starting point measures with a sextant the angle subtended by the length on the rod. Say it is 50 minutes. Then the distance to the rod is 100 multiplied by 100 and divided by 50, or 200 meters. The azimuth is obtained with the prismatic compass, the points are marked, and the topographer follows the rodman as in case (*a*).

Use of boat for observing platform.—The following method has been used to advantage in shallow water: A large flat-bottom boat is fitted with two loops on each side and a three-armed high-sided well in the bottom (see fig. 25). Poles are stuck through the four loops into the mud, thus holding the boat rigid. Three stakes, one in each arm of the well, are driven into the mud, their tops level with the water. The tripod legs are set on the tops of these stakes. Thus,

the plane table is set up and the boat used as a platform on which the topographer stands, it being prevented by the poles from jarring the table. The table is then used in the customary manner.

JUNCTION OF SHEETS

The topographer must always remember that each field sheet is only one of many that go to make up the published chart or map. His sheet will join that surveyed or to be surveyed by some other topographer. Consequently, special care should be taken to see that the work on the edges of his sheet is adequately controlled and sur-

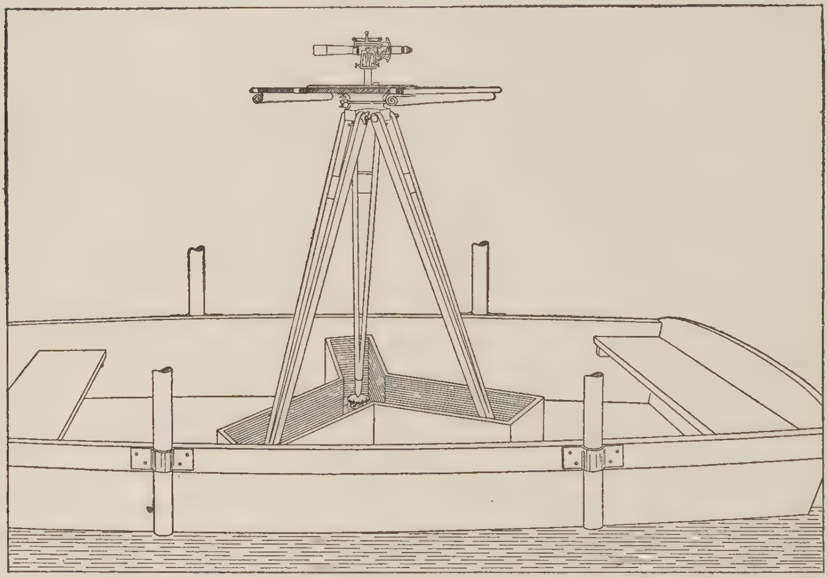

FIG. 25.—Use of boat as observing platform

veyed with a minimum of error. In the Coast and Geodetic Survey the shore line delineated on a sheet usually terminates at a control station. There is no such fixed point for the contours, however. The ends of the contours, therefore, should be given special care and not drawn beyond the distance of his shore line unless warranted by the control. On the other hand, it must be remembered that the edge of the adjoining sheet also will be difficult to contour. Therefore, the topographer should carry his survey to a logical connection with the adjoining sheet.

Slight discrepancies should be adjusted by the topographer, but should the discrepancies be of a magnitude which can not be reconciled by slight adjustments, then the new work should be carried to a point where a good joining can be effected. Should the old work

require radical revision, additional instructions should be requested. All discrepancies on adjoining contemporaneous sheets must be reconciled by the field parties.

Extension on subplan.—It is sometimes desired to include on a sheet a small area that lies just beyond the edge of the sheet. A convenient method of accomplishing this is illustrated in Figure 26. Set-up point No. 1 having been established from control station *a*, it is desired to extend the work a short distance beyond point No. 1. The procedure is as follows:

On an unused part of the sheet lay off the limits of a subplan of suitable size. The projection lines of the sheet are also used for

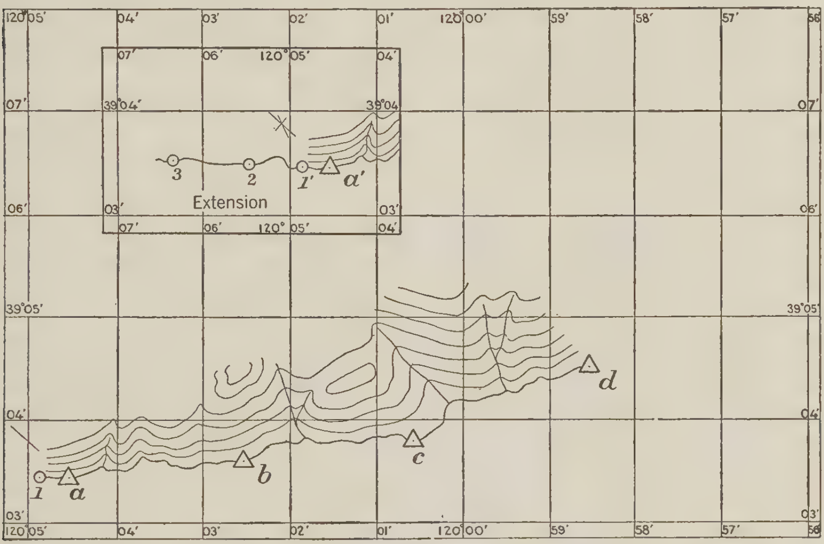

FIG. 26.—Extension of work on subplan

the subplan, their designations being changed so that the subplan covers the area desired. Thus, in the illustration, the projection line for the meridian 120° 02′ on the sheet becomes the line for the meridian 120° 05′ on the subplan; the line for latitude 39° 07′ is changed to latitude 39° 04′, etc.

Plot the position of set-up point No. 1 on the subplan (at point No. 1′) in its proper position with respect to the projection lines of the plan. Set up and orient the table at point No. 1 on the ground, using the positions plotted on the sheet and the orientation lines that were drawn for the cut from station *a*. As the same projection lines are used both for the sheet and subplan, the table is also properly oriented for work on the latter. Continue work in the usual manner from point No. 1′ on the subplan.

If a cut has been observed to some object from a previous station, such as station *a*, it can be transferred to the subplan and used with other cuts, observed from stations plotted on the plan, to locate the object.

This method can also be used to survey a small area on a larger scale than the rest of the work. In all cases, on account of the change in length of intervals between projection lines, this procedure must be confined to the survey of small areas and to work on scales of 1:20,000 or larger.

NOTES

The topographer should keep a notebook in which to enter the following information, obtained during the course of the survey. He should rely on memory as little as possible.

1. Geographic names and information concerning them as required by paragraph 64, part 1.
2. General information for the descriptive report (see pars. 65 and 66, p. 1).
3. Description of objects to which cuts are taken.
4. Statistics required (on Form 21) for reports of field work.
5. Coast Pilot notes (see par. 61, p. 1).
6. Miscellaneous information.

It is well to form the habit of making copious notes as the survey progresses. Often the writing of notes on one subject will call the attention of the writer to other information desired which he might otherwise have failed to obtain.

REVISION SURVEYS

Revision surveys are one of the most difficult classes of topographic work that the topographer will encounter. To make a proper revision quickly and yet show clearly all new features as well as those previously mapped that have either changed in position, were erroneously located by the old survey, or are no longer in existence, requires great skill and the utmost care to avoid confusion or doubt when the changes are noted in chart compilation.

Many of the old surveys show much detail and conform to the present standards of accuracy. When new surveys disagree with the old, it is impossible for the cartographer to reconcile the differences unless they are shown clearly, with a preponderance of evidence in favor of the new work. When a new position of a rock is given, the cartographer is unable to ascertain, from the delineation on the sheet, whether there are two rocks or, if only one rock, which of the positions is correct. If one rock awash is shown where the old survey shows two such rocks, the former survey may be in error or the

revision topographer may have carried on his work when one of the rocks was covered.

If there are changes in the shore line, the cartographer may have difficulty in fitting the details of former surveys to the new work unless decisive information is furnished by the revision topographer.

One of the most important duties of the topographer engaged in revision work, therefore, is to note and investigate all discrepancies between the new and old work and to furnish complete and definite information, either by notes on the sheet or in the descriptive report, for the guidance of the cartographer.

The value of information such as is given in the two sample notes below is obvious:

The rock 100 meters northeastward of Point High, as located by the survey, is 45 meters south of the position given by the old survey (topographic sheet 3623). It was located on the present sheet by an exact intersection of three cuts from triangulation stations Dog, Hall, and Sun. It was definitely established by an examination at extreme low water that there is only one rock in this locality.

The positions of the two rocks in the entrance to Narrow Inlet was verified by the resurvey. The old survey shows both rocks extending above high tide. On April 3, 1927, at 3.15 p. m. (2 hours before high tide according to the tide tables), it was noted that the northern rock was only about 3 inches above water, and it is therefore shown as a rock awash.

For revision surveys the topographer is usually furnished with bromide copies of the original surveys and a list of control stations. He should first make a visual comparison of the old survey with existing features, noting the extent of changes.

If there are few changes and numerous control points, it is sometimes practicable to use the bromide for a plane-table sheet. New features, changes, and features to be removed are shown in colored ink, as prescribed in paragraph 53, part 1.

The use of bromide copies, as indicated above, however, is very limited, as the paper is brittle and subject to large distortion. For surveys of any great extent it is desirable to use standard topographic sheets. A projection is constructed as for ordinary topographic work, and the parts of the old survey to be revised are transferred from the bromide.

The old work should be traced on tracing paper (not cloth) and transferred lightly to the topographic sheet by means of transfer paper. Special, thin, red, hard-finish transferring paper is furnished by the office of the Coast and Geodetic Survey, or satisfactory paper can be made in the field by scraping the lead of a very soft pencil on a thin sheet of paper and rubbing the powdered lead into the paper. Ordinary carbon paper should not be used.

When work is done in this manner, the bromide should be carried with the topographic sheet, so that comparisons can be made at any time.

When surveying along an outer beach, the entrance points to indentations must be surveyed back to a point where the old and new shore lines coincide. Islands in entrances should be surveyed in the same manner.

Occasionally minor corrections are made directly on an existing chart when the chart has a scale of 1:40,000 or larger.

Care must be exercised that the size of new features is not exaggerated but kept to the same scale as the chart. These corrections are inked in red. The corrected chart is considered as a topographic sheet in all respects and is subject to the same requirements for field and office work by the field party as an original sheet, in so far as they apply.

If a minor revision is to be made, such as locating a new dock when a projection is not possible because geographic positions of control points are lacking, no bromide copy of the original survey is on hand, and the existing chart is on too small a scale, the revision can be made on a plane-table sheet as for a survey without control. From some starting point clearly indicated on the new work, such as a corner of the dock, lines are drawn to three or more visible and charted objects, such as stacks, rocks, points of shore line, or tangents to islands. The work is then executed with this orientation. The chart compiler ties the revision onto the existing survey with these lines. A note must be made on the sheet as to the scale of the work, because, if it is omitted, the cartographer has no way of determining the scale. Part of the adjacent shore line or charted topographic features should be determined for an additional tie or check.

PHOTOGRAPHY

Although photographic methods of topographic surveying have been used for many years, the advent of the airplane has increased the importance of this branch of the work.

The usual topographic requirements for chart construction are for a survey of a comparatively narrow strip along the coast. This simplifies the use of aerial phototopography by the Coast and Geodetic Survey.

The fitting of the photographs to the linear distances between the control points, with corresponding lateral expansion or contraction, forms the basis of adjustment. Machines have been invented to transfer topographic features, including contours, directly from aerial photographs to the map.

The methods of taking photographs and for reproducing the information on maps are in process of development as this is written, and no attempt will be made to describe them here.

The most extensive use of aerial photography for mapping by the Coast and Geodetic Survey is described in Special Publication No. 105. Aerial Survey of the Mississippi River Delta.

Part 4.—OFFICE WORK

On days when field work can not be done, advantage should be taken of the opportunity to compute elevations, sketch in form lines smoothly that have been indicated or drawn roughly in the field, make adjustments of traverse, refresh features that have become dim, make notes on the sheet, plot auxiliary surveys, and write notes for the descriptive report. No inking should be done until the sheet is completed. If these things are done while the details are fresh in the mind of the topographer, many errors and subsequent hard work will be avoided.

It is taken for granted that the topography as drawn in the field is correct when the sheet is finished, and no office amendments or changes are admissible.

INKING SHEETS

As prescribed in paragraph 32, part 1, no inking is to be done on the sheet until all field work on it is completed. An inked or partially inked sheet may be ruined by exposure to the weather or by use on the plane table.

In inking a topographic sheet the lines and objects should be clear and sharply defined, nothing being left obscure or doubtful. The paper should be kept as clean as possible, erasures should be avoided as far as practicable, and the style and strength of the drawing should be the same throughout. It is important that an easy and natural appearance should be given to the sheet; more than a mere rigid adherence to conventional symbols is necessary. While there should be no deviation as regards symbols, at the same time the draftsman should strive to represent the country as it actually appears.

There is a great difference with regard to this among topographers. Comparing two correct sheets of the same section of ground, executed by different persons, one may have a stiff and ungraceful look, while the other will appear artistic and natural, giving at once the impression of a true representation of the country surveyed.

The inking should begin with the high and low water lines. The high-water line, or shore-line proper, should be full and black, the heaviest line on the sheet, and in this, as in all the rest of the ink work, strict adherence to the lines of the surveyor should be observed.

The low-water line is drawn, not so full as the high-water line, but clear, black, and uniform; it should consist of a dotted line for sand and mud and the conventional symbol where it is formed by shells, rocks, or coral reefs.

Neither the inner border of a marsh nor a shoal covered at high tide has a distinct continuous line to mark its limits, each being represented in its proper form and within its area by its conventional symbol only, but the shape should be well and correctly defined. All objects between high and low water, covered at full tide, should be represented less boldly than the other features on the sheet, but not faintly or indefinitely.

Roads should be inked plainly and evenly, with their sides parallel, except where the survey shows a deviation from the general width. Care must be taken that the corners and angles of houses, wharves, etc., exhibit a sharp, clear outline, which adds much to the appearance of the sheet.

The general skeleton of the survey being now completed, the contours are drawn with bold, uniform, plain, red lines (without breaks, except for the contour numbers) over all the other work, following accurately the full range of level of each of the contours on the sheet.

After this comes the general filling in, by conventional symbols, of sand, marsh, grass, cultivation, orchards, rocks, hachures, etc. Some practice is needed to execute the sand work regularly and neatly. It should never be done hurriedly, though, of course, rapidity in this respect follows practice. The lines representing marsh, and the delineation of grass on the fast ground, should always run in the same direction over the whole sheet and be parallel to the parallels of latitude of the sheet.

The standard symbols adopted by the United States Board of Surveys and Maps, and several reproductions of sections of topographic sheets, are given in the appendix.

It is expected that every topographer shall have learned to draw sufficiently well to ink his sheet in a clear and distinct manner and letter it with some regard to neatness and graphic effect, as the appearance of an otherwise well-inked sheet is marred by careless or indifferent lettering. Accuracy, neatness, and clearness are necessary, rather than fine draftsmanship.

Names should be so located on the sheet that they will not cover or obliterate any detail or feature of the survey. The letters should be put on neatly and gracefully and should conform in style to the standard lettering shown in Figure 37, page 114. Strict adherence to simplicity should be observed; no illuminated or German text, old English, or what is known as " fancy printing " should be used. The

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use of capitals and lower-case letters and the graduation in sizes of letters will depend on the relative importance of the features named. (See pars. 45 to 48, pt. 1.)

The lettering should be placed, as far as practicable, so that it can be read easily when the sheet is held with the top (the north end of the map) away from the observer; that is, as nearly parallel with the north side of the sheet as the work will permit.

When buoys are located by the topographer, their names, colors, numbers, etc., should be indicated by notes.

Requirements for inking revision work are given in paragraphs 53 and 54, part 1. After the inking is completed, it will usually be necessary to freshen the unrevised work which is left in pencil.

APPENDIX

MISCELLANEOUS TABLES

TABLE 1.—*For reducing readings of inclined sights on a rod held perpendicular to the line of sight*

Angle (degrees)	Hypotenuse				
	100 meters	200 meters	300 meters	400 meters	500 meters
5	99. 62	199. 24	298. 86	398. 48	498. 10
10	98. 48	196. 96	295. 44	393. 92	492. 40
15	96. 59	193. 19	289. 78	386. 37	482. 96
20	93. 97	187. 94	281. 91	375. 88	469. 85
25	90. 63	181. 26	271. 89	362. 52	453. 15
30	86. 60	173. 21	259. 81	346. 41	433. 01
35	81. 92	163. 83	245. 75	327. 66	409. 58
40	76. 60	153. 21	229. 81	306. 42	383. 02
45	70. 71	141. 42	212. 13	282. 84	353. 55

NOTE.—When it is desired to have the rod perpendicular to the line of sight, a sighting pointer must be provided on the rod as explained on page 77.

TABLE 2

FOR REDUCING READINGS OF INCLINED SIGHTS ON A VERTICAL ROD

Two corrections are to be applied—one to reduce the inclined distance to a horizontal one and one for the oblique view of the rod.

The equation for reducing the readings is:

$$\text{Horizontal distance} = r \cos^2 v + (c+f) \cos v$$

Where r=reading of vertical rod;
v=angle of elevation or depression;
c=distance of object glass to center of instrument;
f=focal length of telescope.

The following table gives the coefficient of reduction by which the rod reading is to be multiplied. It is based on the assumption that $c+f$ is to be added to the result, to obtain the distance to the center of the instrument, if necessary.

Example: Given an angle of elevation or depression 8° 10′ and the reading of the inclined sight on vertical rod=173.1 meters.

From the following table:

	Meters
Factor for 1 meter for 8° 10′ multiplied by 100	97. 98
Factor for 7 meter for 8° 10′ multiplied by 10	68. 59
Factor for 3 meter for 8° 10′	2. 94
Factor for 0.1 meter for 8° 10′	. 09
Horizontal distance	169. 60

To which $c+f$ is to be added.

TABLE 2—Continued

COEFFICIENTS FOR REDUCING READINGS OF INCLINED SIGHTS ON A VERTICAL ROD TO HORIZONTAL DISTANCE

Angle of inclination	Horizontal projection of—								
	1 m.	2 m.	3 m.	4 m.	5 m.	6 m.	7 m.	8 m.	9 m.
° ′									
0 10	0. 99999	1. 99998	2. 99997	3. 99997	4. 99996	5. 99994	6. 99994	7. 99993	8. 99993
20	. 99997	1. 99993	2. 99990	3. 99986	4. 99983	5. 99980	6. 99977	7. 99973	8. 99970
30	. 99992	1. 99984	2. 99977	3. 99969	4. 99962	5. 99954	6. 99946	7. 99939	8. 99932
40	. 99986	1. 99973	2. 99959	3. 99946	4. 99952	5. 99919	6. 99905	7. 99892	8. 99878
50	. 99979	1. 99957	2. 99936	3. 99915	4. 99894	5. 99873	6. 99852	7. 99831	8. 99810
1 00	. 99970	1. 99939	2. 99909	3. 99878	4. 99848	5. 99817	6. 99787	7. 99757	8. 99726
10	. 99959	1. 99917	2. 99875	3. 99834	4. 99793	5. 99752	6. 99711	7. 99669	8. 99628
20	. 99946	1. 99891	2. 99838	3. 99783	4. 99729	5. 99676	6. 99622	7. 99568	8. 99514
30	. 99932	1. 99863	2. 99794	3. 99725	4. 99657	5. 99589	6. 99520	7. 99452	8. 99384
40	. 99915	1. 99831	2. 99746	3. 99659	4. 99572	5. 99489	6. 99406	7. 99323	8. 99239
50	. 99908	1. 99801	2. 99693	3. 99590	4. 99488	5. 99386	6. 99284	7. 99182	8. 99080
2 00	. 99878	1. 99756	2. 99635	3. 99513	4. 99391	5. 99269	6. 99147	7. 99025	8. 98904
10	. 99857	1. 99714	2. 99571	3. 99428	4. 99285	5. 99142	6. 99000	7. 98857	8. 98714
20	. 99834	1. 99669	2. 99503	3. 99337	4. 99171	5. 99006	6. 98840	7. 98675	8. 98509
30	. 99810	1. 99620	2. 99429	3. 99239	4. 99049	5. 98859	6. 98669	7. 98479	8. 98289
40	. 99784	1. 99568	2. 99351	3. 99135	4. 98918	5. 98702	6. 98485	7. 98268	8. 98053
50	. 99756	1. 99511	2. 99267	3. 99023	4. 98778	5. 98534	6. 98290	7. 98046	8. 97802
3 00	. 99726	1. 99452	2. 99178	3. 98904	4. 98630	5. 98357	6. 98083	7. 97809	8. 97635
10	. 99695	1. 99390	2. 99085	3. 98780	4. 98474	5. 98169	6. 97865	7. 97560	8. 97255
20	. 99662	1. 99324	2. 98986	3. 98648	4. 98309	5. 97972	6. 97634	7. 97296	8. 96958
30	. 99627	1. 99255	2. 98882	3. 98509	4. 98136	5. 97764	6. 97391	7. 97019	8. 96646
40	. 99591	1. 99182	2. 98773	3. 98364	4. 97955	5. 97546	6. 97137	7. 96728	8. 96319
50	. 99553	1. 99106	2. 98659	3. 98212	4. 97765	5. 97318	6. 96871	7. 96424	8. 95978
4 00	. 99513	1. 99027	2. 98540	3. 98054	4. 97567	5. 97081	6. 96595	7. 96108	8. 95621
10	. 99472	1. 98944	2. 98416	3. 97888	4. 97360	5. 96832	6. 96304	7. 95776	8. 95249
20	. 99429	1. 98858	2. 98287	3. 97716	4. 97145	5. 96574	6. 96003	7. 95432	8. 94862
30	. 99384	1. 98769	2. 98153	3. 97537	4. 96922	5. 96306	6. 95691	7. 95075	8. 94460
40	. 99338	1. 98676	2. 98014	3. 97352	4. 96690	5. 96028	6. 95366	7. 94704	8. 94043
50	. 99290	1. 98580	2. 97870	3. 97160	4. 96450	5. 95740	6. 95030	7. 94320	8. 93611
5 00	. 99240	1. 98481	2. 97721	3. 96961	4. 96202	5. 95443	6. 94683	7. 93923	8. 93164
10	. 99189	1. 98378	2. 97567	3. 96756	4. 95945	5. 95134	6. 94323	7. 93512	8. 92702
20	. 99136	1. 98272	2. 97408	3. 96544	4. 95680	5. 94816	6. 93952	7. 93088	8. 92224
30	. 99081	1. 98163	2. 97244	3. 96326	4. 95407	5. 94489	6. 93570	7. 92652	8. 91733
40	. 99025	1. 98050	2. 97075	3. 96100	4. 95125	5. 94150	6. 93175	7. 92200	8. 91225
50	. 98967	1. 97934	2. 96901	3. 95868	4. 94835	5. 93802	6. 92769	7. 91736	8. 90703
6 00	. 98907	1. 97814	2. 96722	3. 95630	4. 94537	5. 93445	6. 92358	7. 91260	8. 90167
10	. 98846	1. 97692	2. 96538	3. 95384	4. 94230	5. 93077	6. 91923	7. 90769	8. 89615
20	. 98783	1. 97566	2. 96349	3. 95132	4. 93915	5. 92698	6. 91481	7. 90264	8. 89048
30	. 98718	1. 97436	2. 96155	3. 94873	4. 93591	5. 92310	6. 91029	7. 89748	8. 88467
40	. 98652	1. 97304	2. 95956	3. 94609	4. 93261	5. 91913	6. 90566	7. 89218	8. 87870
50	. 98584	1. 97169	2. 95753	3. 94337	4. 92921	5. 91506	6. 90090	7. 88674	8. 87259
7 00	. 98515	1. 97030	2. 95544	3. 94059	4. 92574	5. 91089	6. 89604	7. 88119	8. 86634
10	. 98444	1. 96888	2. 95331	3. 93775	4. 92218	5. 90662	6. 89105	7. 87549	8. 85993
20	. 98371	1. 96742	2. 95112	3. 93483	4. 91854	5. 90225	6. 88596	7. 86967	8. 85337
30	. 98296	1. 96592	2. 94889	3. 93185	4. 91481	5. 89777	6. 88073	7. 86370	8. 84667
40	. 98220	1. 96441	2. 94661	3. 92881	4. 91101	5. 89322	6. 87542	7. 85762	8. 83982
50	. 98142	1. 96285	2. 94427	3. 92570	4. 90712	5. 88855	6. 86997	7. 85140	8. 83282

TABLE 2—Continued

COEFFICIENTS FOR REDUCING READINGS OF INCLINED SIGHTS ON A VERTICAL ROD TO HORIZONTAL DISTANCE

Angle of inclination		Horizontal projection of—								
		1 m.	2 m.	3 m.	4 m.	5 m.	6 m.	7 m.	8 m.	9 m.
°	′									
8	00	0.98063	1.96126	2.94189	3.92252	4.90315	5.88378	6.86441	7.84504	8.82568
	10	.97982	1.95964	2.93946	3.91928	4.89910	5.87892	6.85874	7.83856	8.81839
	20	.97899	1.95798	2.93698	3.91598	4.89497	5.87396	6.85296	7.83196	8.81096
	30	.97815	1.95630	2.93446	3.91261	4.89076	5.86891	6.84707	7.82522	8.80337
	40	.97729	1.95459	2.93188	3.90918	4.88647	5.86377	6.84106	7.81836	8.79565
	50	.97642	1.95284	2.92926	3.90568	4.88209	5.85851	6.83493	7.81134	8.78777
9	00	.97553	1.95106	2.92658	3.90211	4.87764	5.85317	6.82870	7.80423	8.77975
	10	.97462	1.94924	2.92386	3.89848	4.87310	5.84772	6.82234	7.79696	8.77159
	20	.97370	1.94740	2.92110	3.89480	4.86849	5.84219	6.81589	7.78959	8.76328
	30	.97276	1.94552	2.91828	3.89104	4.86379	5.83655	6.80931	7.78207	8.75483
	40	.97180	1.94361	2.91542	3.88722	4.85902	5.83083	6.80263	7.77444	8.74624
	50	.97083	1.94166	2.91250	3.88333	4.85416	5.82499	6.79583	7.76667	8.73750
10	00	.96985	1.93970	2.90954	3.87938	4.84923	5.81907	6.78892	7.75876	8.72861
	10	.96884	1.93769	2.90653	3.87537	4.84421	5.81306	6.78190	7.75074	8.71959
	20	.96782	1.93565	2.90347	3.87129	4.83912	5.80695	6.77477	7.74259	8.71042
	30	.96679	1.93358	2.90037	3.86716	4.83395	5.80074	6.76753	7.73432	8.70111
	40	.96574	1.93148	2.89721	3.86295	4.82869	5.79443	6.76017	7.72591	8.69165
	50	.96467	1.92934	2.89402	3.85869	4.82336	5.78803	6.75271	7.71738	8.68206
11	00	.96359	1.92718	2.89077	3.85436	4.81795	5.78154	6.74513	7.70872	8.67232
	10	.96249	1.92498	2.88748	3.84997	4.81247	5.77496	6.73746	7.69995	8.66245
	20	.96138	1.92276	2.88414	3.84552	4.80690	5.76828	6.72966	7.69104	8.65242
	30	.96025	1.92051	2.88076	3.84101	4.80126	5.76152	6.72177	7.68202	8.64227
	40	.95911	1.91822	2.87732	3.83643	4.79553	5.75464	6.71375	7.67286	8.63196
	50	.95795	1.91590	2.87385	3.83180	4.78974	5.74769	6.70564	7.66358	8.62153
12	00	.95677	1.91355	2.87032	3.82709	4.78386	5.74063	6.69741	7.65418	8.61095
	10	.95558	1.91116	2.86674	3.82232	4.77790	5.73348	6.68906	7.64464	8.60023
	20	.95438	1.90876	2.86313	3.81750	4.77187	5.72625	6.68062	7.63500	8.58938
	30	.95315	1.90631	2.85946	3.81261	4.76576	5.71892	6.67207	7.62522	8.57838
	40	.95192	1.90384	2.85575	3.80766	4.75958	5.71150	6.66341	7.61533	8.56724
	50	.95066	1.90132	2.85199	3.80265	4.75332	5.70399	6.65465	7.60532	8.55598
13	00	.94940	1.89880	2.84820	3.79759	4.74698	5.69638	6.64577	7.59516	8.54456
	10	.94811	1.89623	2.84434	3.79245	4.74056	5.68868	6.63679	7.58491	8.53302
	20	.94682	1.89364	2.84045	3.78726	4.73407	5.68088	6.62770	7.57452	8.52133
	30	.94550	1.89101	2.83651	3.78201	4.72751	5.67301	6.61852	7.56402	8.50952
	40	.94417	1.88835	2.83252	3.77669	4.72087	5.66505	6.60922	7.55339	8.49757
	50	.94283	1.88566	2.82849	3.77132	4.71415	5.65698	6.59981	7.54264	8.48548
14	00	.94147	1.88295	2.82442	3.76589	4.70736	5.64884	6.59031	7.53179	8.47326
	10	.94010	1.88020	2.82030	3.76040	4.70050	5.64060	6.58070	7.52080	8.46090
	20	.93871	1.87742	2.81613	3.75484	4.69355	5.63226	6.57097	7.50968	8.44840
	30	.93731	1.87462	2.81192	3.74923	4.68654	5.62385	6.56115	7.49846	8.43578
	40	.93589	1.87178	2.80767	3.74356	4.67945	5.61534	6.55123	7.48712	8.42302
	50	.93446	1.86892	2.80338	3.73784	4.67229	5.60675	6.54121	7.47567	8.41013
15	00	.93301	1.86602	2.79903	3.73204	4.66505	5.59806	6.53107	7.46408	8.39710
16	00	.92402	1.84805	2.77208	3.69610	4.62011	5.54414	6.46816	7.39218	8.31620
17	00	.91452	1.82904	2.74355	3.65806	4.57258	5.48710	6.40161	7.31613	8.23065
18	00	.90451	1.80902	2.71352	3.61803	4.52253	5.42704	6.33154	7.23605	8.14056
19	00	.89400	1.78800	2.68201	3.57600	4.47001	5.36402	6.25802	7.15203	8.04603
20	00	.88302	1.76604	2.64906	3.53208	4.41510	5.29812	6.18114	7.06416	7.94718

TABLE 3.—*Factors for computing differences in elevation*

[To obtain the difference in elevation in feet, multiply the horizontal distance in meters by the factor in this table corresponding to the observed angle of elevation or depression. The factors are given for each 10 minutes, but the value for the nearest minute may be interpolated, using the column of differences for 1 minute. The result is still to be corrected where necessary for the effect of curvature and refraction]

Angle, degrees	0′	10′	20′	30′	40′	50′	60′	Difference for 1 minute (fourth decimal place)
0	0. 0000	0. 0095	0. 0191	0. 0286	0. 0382	0. 0477	0. 0573	9. 5
1	0. 0573	0. 0668	0. 0764	0. 0859	0. 0955	0. 1050	0. 1146	9. 6
2	0. 1146	0. 1241	0. 1337	0. 1432	0. 1528	0. 1624	0. 1719	9. 6
3	0. 1719	0. 1815	0. 1911	0. 2007	0. 2102	0. 2198	0. 2294	9. 6
4	0. 2294	0. 2390	0. 2486	0. 2582	0. 2678	0. 2774	0. 2870	9. 6
5	0. 2870	0. 2967	0. 3063	0. 3159	0. 3255	0. 3352	0. 3448	9. 6
6	0. 3448	0. 3545	0. 3641	0. 3738	0. 3835	0. 3932	0. 4028	9. 7
7	0. 4028	0. 4125	0. 4222	0. 4319	0. 4416	0. 4514	0. 4611	9. 7
8	0. 4611	0. 4708	0. 4806	0. 4903	0. 5001	0. 5098	0. 5196	9. 8
9	0. 5196	0. 5294	0. 5392	0. 5490	0. 5588	0. 5687	0. 5785	9. 8
10	0. 5785	0. 5884	0. 5982	0. 6081	0. 6179	0. 6278	0. 6377	9. 9
11	0. 6377	0. 6476	0. 6576	0. 6675	0. 6774	0. 6874	0. 6974	9. 9
12	0. 6974	0. 7073	0. 7173	0. 7273	0. 7374	0. 7474	0 7574	10. 0
13	0. 7574	0. 7675	0. 7776	0. 7877	0. 7978	0. 8079	0. 8180	10. 1
14	0. 8180	0. 8282	0. 8383	0. 8485	0. 8587	0. 8689	0. 8791	10. 2
15	0. 8791	0. 8893	0. 8996	0. 9099	0. 9201	0. 9304	0. 9408	10. 3
16	0. 9408	0. 9511	0. 9615	0. 9718	0. 9822	0. 9926	1. 0031	10. 4
17	1. 0031	1. 0135	1. 0240	1. 0344	1. 0449	1. 0555	1. 0660	10. 5
18	1. 0660	1. 0766	1. 0872	1. 0978	1. 1084	1. 1190	1. 1297	10. 6
19	1. 1297	1. 1404	1. 1511	1. 1618	1. 1726	1. 1833	1. 1941	10. 7
20	1. 1941	1. 2050	1. 2158	1. 2266	1. 2375	1. 2485	1. 2594	10. 9
21	1. 2594	1. 2704	1. 2813	1. 2924	1. 3034	1. 3144	1. 3255	11. 0
22	1. 3255	1. 3367	1. 3478	1. 3590	1. 3702	1. 3814	1. 3926	11. 2
23	1. 3926	1. 4039	1. 4152	1. 4266	1. 4379	1. 4493	1. 4607	11. 4
24	1. 4607	1. 4722	1. 4836	1. 4952	1. 5067	1. 5183	1. 5299	11. 5
25	1. 5299	1. 5415	1. 5532	1. 5649	1. 5766	1. 5884	1. 6002	11. 7
26	1. 6002	1. 6120	1. 6239	1. 6358	1. 6477	1. 6597	1. 6717	11. 9
27	1. 6717	1. 6837	1. 6958	1. 7079	1. 7200	1. 7322	1. 7444	12. 1
28	1. 7444	1. 7567	1. 7690	1. 7814	1. 7937	1. 8061	1. 8186	12. 4
29	1. 8186	1. 8311	1. 8436	1. 8562	1. 8688	1. 8815	1. 8942	12. 6
30	1. 8942	1. 9069	1. 9197	1. 9326	1. 9454	1. 9584	1. 9713	12. 9
31	1. 9713	1. 9843	1. 9974	2. 0105	2. 0236	2. 0368	2. 0501	13. 1
32	2. 0501	2. 0634	2. 0767	2. 0901	2. 1036	2. 1171	2. 1306	13. 4
33	2. 1306	2. 1442	2. 1578	2. 1715	2. 1853	2. 1991	2. 2130	13. 7
34	2. 2130	2. 2269	2. 2408	2. 2548	2. 2689	2. 2831	2. 2973	14. 0
35	2. 2973	2. 3115	2. 3258	2. 3402	2. 3546	2. 3691	2. 3837	14. 4
36	2. 3837	2. 3983	2. 4130	2. 4277	2. 4425	2. 4574	2. 4723	14. 8
37	2. 4723	2. 4873	2. 5023	2. 5175	2. 5327	2. 5479	2. 5633	15. 2
38	2. 5633	2. 5787	2. 5942	2. 6097	2. 6253	2. 6410	2. 6568	15. 6
39	2. 6568	2. 6726	2. 6885	2. 7045	2. 7206	2. 7367	2. 7530	16. 0
40	2. 7530	2. 7692	2. 7856	2. 8021	2. 8186	2. 8353	2. 8520	16. 5
41	2. 8520	2. 8688	2. 8857	2. 9026	2. 9197	2. 9368	2. 9541	17. 0
42	2. 9541	2. 9714	2. 9888	3. 0063	3. 0239	3. 0416	3. 0594	17. 6
43	3. 0594	3. 0773	3. 0953	3. 1134	3. 1316	3. 1499	3. 1683	18. 1
44	3. 1683	3. 1868	3. 2054	3. 2241	3. 2429	3. 2618	3. 2808	18. 8

TABLE 4.—*Corrections for curvature and refraction*

[The correction in feet for the combined effect of curvature and refraction is given for each 100 meters' distance, the thousands of meters being given in the column to the left and the hundreds in the upper line. The correction is to be added to the *difference* of elevation for angles of *elevation* and *subtracted* for angles of *depression,* or it is always to be added to the uncorrected *elevation* of the point to be determined from point of observation. Example: At a station whose elevation is 1,000 feet (at telescope), angle to signal = 3° elevation, horizontal distance = 5,000 meters. From Table 3 factor is 0.1719, which multiplied by 5,000 = 859.5 feet. From Table 4 correction is 5.5 feet. Corrected difference of elevation = 859.5 + 5.5 = 865 feet, which added to 1,000 = 1,865 feet for elevation of signal. If the above angle to signal be 3° depression, then corrected difference of elevation = 859.5 — 5.5 + 854 feet, which makes height of signal = 1,000 — 854 = 146 feet]

Distance in meters	0	100	200	300	400	500	600	700	800	900	1,000
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2
1,000	.2	.3	.3	.4	.4	.5	.6	.6	.7	.8	.9
2,000	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.9	2.0
3,000	2.0	2.1	2.3	2.4	2.6	2.7	2.9	3.0	3.2	3.4	3.5
4,000	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5
5,000	5.5	5.8	6.0	6.2	6.5	6.7	7.0	7.2	7.4	7.7	8.0
6,000	8.0	8.2	8.5	8.8	9.1	9.4	9.7	10.0	10.2	10.6	10.9
7,000	10.9	11.2	11.5	11.8	12.1	12.5	12.8	13.1	13.5	13.8	14.2
8,000	14.2	14.5	14.9	15.3	15.6	16.0	16.4	16.8	17.2	17.6	18.0
9,000	18.0	18.4	18.8	19.2	19.6	20.0	20.4	20.8	21.3	21.7	22.2
10,000	22.2	22.6	23.0	23.5	24.0	24.4	24.9	25.4	25.8	26.3	26.8
11,000	26.8	27.3	27.8	28.3	28.8	29.3	29.8	30.3	30.8	31.4	31.9
12,000	31.9	32.4	33.0	33.5	34.1	34.6	35.2	35.7	36.3	36.9	37.4
13,000	37.4	38.0	38.6	39.2	39.8	40.4	41.0	41.6	42.2	42.8	43.4
14,000	43.4	44.1	44.7	45.3	46.0	46.6	47.2	47.9	48.5	49.2	49.8
15,000	49.8	50.5	51.2	51.9	52.5	53.2	53.9	54.6	55.3	56.0	56.7
16,000	56.7	57.4	58.2	58.9	59.6	60.3	61.0	61.8	62.5	63.3	64.0
17,000	64.0	64.8	65.6	66.3	67.1	67.9	68.6	69.4	70.2	71.0	71.8
18,000	71.8	72.6	73.4	74.2	75.0	75.8	76.7	77.5	78.3	79.1	80.0
19,000	80.0	80.8	81.7	82.5	83.4	84.2	85.1	86.0	86.9	87.7	88.6

Comparison of feet and meters

[1 meter = 3.280869 feet]

Meters	Feet	Feet	Meters.
1	3.2808	1	0.3048
2	6.5617	2	.6096
3	9.8425	3	.9144
4	13.1233	4	1.2192
5	16.4042	5	1.5240
6	19.6850	6	1.8288
7	22.9658	7	2.1336
8	26.2467	8	2.4384
9	29.5275	9	2.7432

TABLE 5.—*Horizontal distance in meters corresponding to difference of elevation of 100 feet*

Slope (degrees)	Horizontal distance in meters	Slope (degrees)	Horizontal distance in meters	Slope (degrees)	Horizontal distance in meters
1	1,745	11	157	26	62.5
1½	1,164	12	143	27	59.8
2	873	13	132	28	57.3
2½	698	14	122	29	55.0
3	582	15	114	30	52.8
3½	498	16	106	31	50.7
4	436	17	99.7	32	48.7
4½	387	18	93.8	33	46.9
5	348	19	88.5	34	45.2
5½	317	20	83.7	35	43.5
6	290	21	79.4	36	41.9
7	248	22	75.5	37	40.4
8	217	23	71.8	38	39.0
9	192	24	68.5	39	37.6
10	173	25	65.4	40	36.3

TABLE 6.—*Height in feet corresponding to a given angle of elevation and a given distance in meters* [1]

Meters		300	400	500	600	700	800	900	1,000	1,100
Angle °	′	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
0	1	0.3	0.4	0.6	0.6	0.8	0.9	1.0	1.2	1.3
	2	.6	.8	1.0	1.2	1.5	1.7	1.9	2.1	2.4
	3	.9	1.2	1.5	1.8	2.2	2.5	2.8	3.1	3.4
	4	1.2	1.5	2.0	2.4	2.8	3.2	3.6	4.1	4.5
	5	1.5	1.9	2.4	2.9	3.5	4.0	4.5	5.0	5.5
0	6	1.8	2.3	2.9	3.5	4.2	4.8	5.3	5.9	6.6
	7	2.1	2.7	3.4	4.1	4.8	5.5	6.2	6.9	7.6
	8	2.4	3.1	3.9	4.6	5.5	6.3	7.1	7.9	8.7
	9	2.7	3.5	4.4	5.2	6.2	7.0	7.9	8.8	9.7
	10	2.9	3.8	4.9	5.8	6.8	7.8	8.8	9.8	10.8
0	11	3.2	4.2	5.3	6.4	7.5	8.6	9.6	10.7	11.8
	12	3.5	4.6	5.8	6.9	8.2	9.3	10.5	11.7	12.9
	13	3.8	5.0	6.3	7.5	8.8	10.1	11.4	12.6	13.9
	14	4.1	5.4	6.8	8.1	9.5	10.9	12.2	13.6	15.0
	15	4.4	5.7	7.2	8.6	10.2	11.6	13.1	14.5	16.0
0	16	4.7	6.1	7.7	9.2	10.8	12.4	13.9	15.5	17.1
	17	4.[illegible]	6.5	8.2	9.8	11.5	13.1	14.8	16.5	18.1
	18	5.2	6.9	8.7	10.4	12.2	13.9	15.7	17.4	19.2
	19	5.5	7.3	9.1	10.9	12.8	14.7	16.5	18.4	20.2
	20	5.8	7.7	9.6	11.5	13.5	15.4	17.4	19.3	21.3
0	21	6.1	8.0	10.1	12.1	14.2	16.2	18.2	20.3	22.3
	22	6.4	8.4	10.6	12.6	14.9	17.0	19.1	21.2	23.4
	23	6.7	8.8	11.1	13.2	15.5	17.7	20.0	22.2	24.4
	24	6.9	9.2	11.5	13.8	16.2	18.5	20.8	23.1	25.5
	25	7.2	9.6	12.0	14.4	16.9	19.3	21.7	24.1	26.5
0	26	7.5	9.9	12.5	14.9	17.5	20.0	22.5	25.0	27.6
	27	7.8	10.3	13.0	15.5	18.2	20.8	23.4	26.0	28.6
	28	8.1	10.7	13.4	16.1	18.9	21.5	24.2	26.9	29.7
	29	8.4	11.1	13.9	16.7	19.5	22.3	25.1	27.9	30.7
	30	8.7	11.5	14.4	17.2	20.2	23.1	26.0	28.9	31.8
0	40	11.5	15.3	19.2	22.9	26.9	30.7	34.6	38.4	42.3
	50	14.4	19.1	23.9	28.7	33.5	38.3	43.2	47.9	52.7
1	00	17.2	22.9	28.7	34.4	40.2	46.0	51.7	57.5	63.3
1	10	20.1	26.7	33.5	40.1	46.9	53.6	60.3	67.0	73.8
1	20	23.0	30.5	38.3	45.8	53.6	61.2	69.0	76.6	84.2
1	30	25.8	34.4	43.0	51.6	60.3	69.0	77.7	86.1	94.7
1	40	28.7	38.2	47.8	57.3	66.9	76.6	86.3	95.6	105.2
1	50	31.6	42.0	52.6	63.0	73.6	84.2	94.9	105.2	115.7
2	00	34.4	45.8	57.4	68.9	80	92	103	115	126
2	30	43.0	57.3	71.7	86.0	100	115	129	144	158
3	00	51.6	68.8	86.2	103.2	120	138	155	172	190
3	30	60.2	80.4	100.5	120.5	141	161	181	201	221
4	00	68.9	91.8	114.8	137.7	161	184	207	230	253

[1] Curvature and refraction taken into account for angles of elevation. This table should not be used for angles of depression.

TABLE 6.—*Height in feet corresponding to a given angle of elevation and a given distance in meters*—Continued

Meters	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000
Angle ° ′	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
0 1	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.7	2.8
2	2.6	2.9	3.1	3.4	3.7	3.9	4.2	4.5	4.7
3	3.8	4.2	4.4	4.8	5.3	5.6	5.9	6.3	6.6
4	4.9	5.4	5.8	6.3	6.8	7.2	7.6	8.1	8.6
5	6.1	6.6	7.1	7.7	8.3	8.8	9.4	9.9	10.5
0 6	7.2	7.9	8.5	9.1	9.8	10.4	11.1	11.7	12.4
7	8.4	9.1	9.8	10.6	11.4	12.1	12.8	13.5	14.3
8	9.5	10.4	11.1	12.0	12.9	13.7	14.5	15.3	16.2
9	10.7	11.6	12.5	13.4	14.4	15.3	16.2	17.2	18.1
10	11.8	12.8	13.8	14.9	15.9	16.9	17.9	19.0	20.0
0 11	13.0	14.1	15.1	16.3	17.5	18.6	19.7	20.8	21.9
12	14.1	15.3	16.5	17.7	19.0	20.2	21.4	22.6	23.8
13	15.2	16.6	17.8	19.2	20.5	21.8	23.1	24.4	25.7
14	16.4	17.8	19.1	20.6	22.0	23.4	24.8	26.2	27.6
15	17.5	19.0	20.5	22.0	23.6	25.0	26.5	28.0	29.5
0 16	18.7	20.3	21.8	23.5	25.1	26.7	28.2	29.9	31.4
17	19.8	21.5	23.1	24.9	26.6	28.3	30.0	31.7	33.4
18	21.0	22.8	24.5	26.3	28.2	29.9	31.7	33.5	35.3
19	22.1	24.0	25.8	27.7	29.7	31.5	33.4	35.3	37.2
20	23.3	25.2	27.2	29.2	31.2	33.2	35.1	37.1	39.1
0 21	24.4	26.5	28.5	30.6	32.7	34.8	36.8	38.9	41.0
22	25.5	27.7	29.8	32.0	34.3	36.4	38.5	40.7	42.9
23	26.7	29.0	31.2	33.5	35.8	38.0	40.3	42.5	44.8
24	27.8	30.2	32.5	34.9	37.3	39.6	42.0	44.3	46.7
25	29.0	31.4	33.8	36.3	38.8	41.3	43.7	46.2	48.6
0 26	30.1	32.7	35.2	37.8	40.4	42.9	45.4	48.0	50.5
27	31.3	33.9	36.5	39.2	41.9	44.5	47.1	49.8	52.4
28	32.4	35.2	37.8	40.6	43.4	46.1	48.8	51.6	54.3
29	33.6	36.4	39.2	42.1	45.0	47.8	50.6	53.4	56.2
30	34.7	37.6	40.5	43.5	46.5	49.4	52.3	55.2	58.2
0 40	46.1	50.0	53.9	57.8	61.7	65.6	69.4	73.3	77.3
50	57.6	62.4	67.2	72.1	77.0	81.8	86.6	91.5	96.3
1 00	69.0	74.8	80.6	86.4	92.3	98.0	104	110	115
1 10	80.5	87.2	93.9	100.7	107.5	114.3	121	128	134
1 20	91.9	99.6	107.3	115.1	123	131	138	146	154
1 30	103.4	112.0	120.7	130	138	147	155	164	173
1 40	115	124	134	144	153	163	173	182	192
1 50	126	137	147	158	169	179	190	200	211
2 00	138	149	161	172	184	195	207	218	230
2 30	172	186	201	215	230	244	259	273	287
3 00	207	224	241	259	276	293	310	328	345
3 30	241	261	281	302	322	342	362	382	402
4 00	276	299	322	345	368	391	414	437	460

Example of use of Table 6

[Angle of elevation from point A to point B, distant from each other 1,756 meters=1° 56′]

° ′	Meters	Feet
1 50	1,700	179.00
1 50	50	5.26
1 50	6	.63
0 06	1,700	10.40
0 06	50	.29
0 06	6	.4
	----------	195.62

Point B is 195.62 feet above point A.

TABLE 7.—*Dip at distances short of the horizon*

[The following table is taken from American Practical Navigator, as published by the United States Hydrographic Office]

Distance of land in sea-miles	Height of the eye above the sea in feet							
	5	10	15	20	25	30	35	40
	′	′	′	′	′	′	′	′
¼	11	23	34	45	57	68	79	91
½	6	12	17	23	28	34	40	45
¾	4	8	12	15	19	23	27	30
1	3	6	9	12	15	17	20	23
1¼	3	5	7	10	12	14	16	19
1½	3	4	6	8	10	12	14	16
2	2	4	5	7	8	9	11	12
2½	2	3	4	6	7	8	9	10
3	2	3	4	5	6	7	8	9
3½	2	3	4	5	6	6	7	8
4	2	3	4	5	5	6	7	7
5	2	3	4	4	5	6	6	7
6	2	3	4	4	5	5	6	6

NOTE.—The numbers of the table below the black lines are the same as for the sea horizon at these heights, the visible horizon corresponding to these heights not being so far distant as the land.

REMINDERS

Important points to be remembered in using the plane table for topographic surveying are summarized below:

1. Plumb point over station for short azimuths.
2. In orienting, see that alidade edge cuts both station points equally.
3. While looking through the telescope at orientation station, press and pull table slightly to assure its solidity.
4. Orient on distant signals and resect on near-by ones.
5. Do not orient on short lines for long cuts. When it is required to orient by a previously drawn short cut, the cut should have been extended by marking short lengths of it 12 to 18 inches from the point.
6. Check orientation of table at completion of work at a station and before drawing important cuts.
7. See that rodmen hold stadia rods vertical by standing squarely on both feet directly behind the rod.
8. Keep points of dividers sharp and protect them when not in use by a small piece of rubber or cork.
9. Keep pencil sharp and, when drawing direction lines, hold it close to edge of alidade at constant angle.
10. See that alidade rule makes close contact with the paper.
11. Mark on the cut with a small circle the approximate position of the point sighted on.
12. Draw magnetic meridian on sheet.
13. Keep sheet clean.
14. Keep bottom of alidade clean.
15. Do not rub alidade over sheet more than necessary. Lift it.
16. Do not let body or arms rest on the table.
17. Be careful not to crush paper rolled up under the board.
18. Watch sheet for distortion errors.
19. Check up before leaving a station to see that everything desired at the station has been obtained.
20. Keep notes for descriptive report.

MEDICAL SUPPLIES

Topographic parties should carry with them at all times a first-aid package. When the party is detached from the ship, the following additional medical supplies should be kept in camp or on the cruising launch This list is, of course, variable, depending upon the locality and the facilities for securing professional attention. A copy of the United States Public Health Manual on Ship Sanitation and First Aid for Merchant Seamen is recommended to be included also.

1. Quinine, 5-grain tablets (for preventing malaria and as a general tonic).
2. Compound cathartic pills (a cathartic).
3. Epsom salts (a cathartic especially valuable for cleaning alimentary tract in diarrhea or ptomaine poisoning).
4. Brown's mixture tablets (for colds and coughs).
5. Tincture of iodine (an antiseptic).
6. Bichloride of mercury (an antiseptic for washing out wounds).
7. Aspirin (for relieving headaches, reducing fever, pain in joints).
8. Bandages and absorbent cotton.
9. Adhesive tape.

WORKS AND STRUCTURES

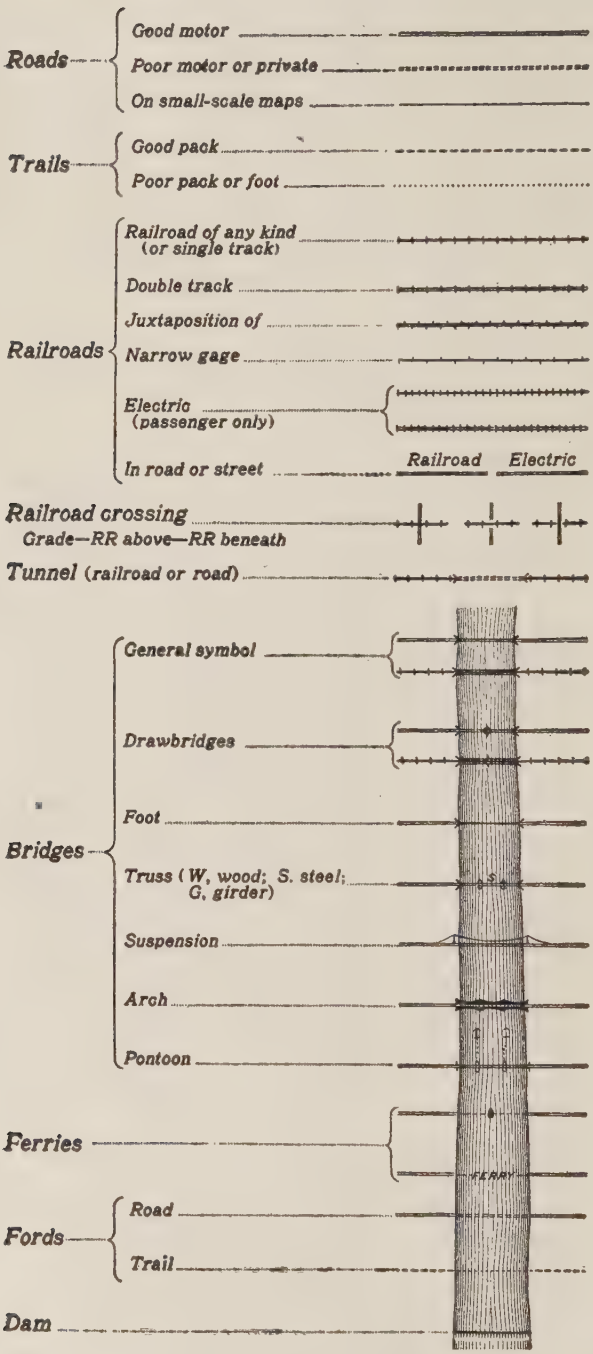

FIG. 27.—Standard symbols

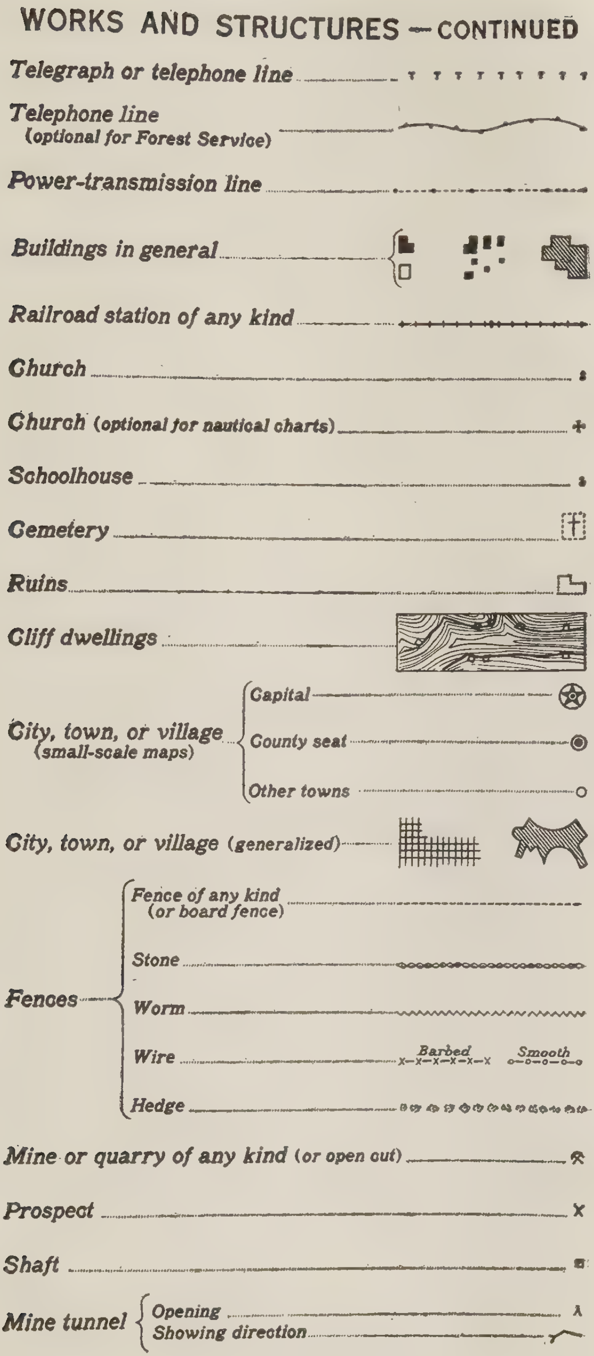

FIG. 28.—Standard symbols

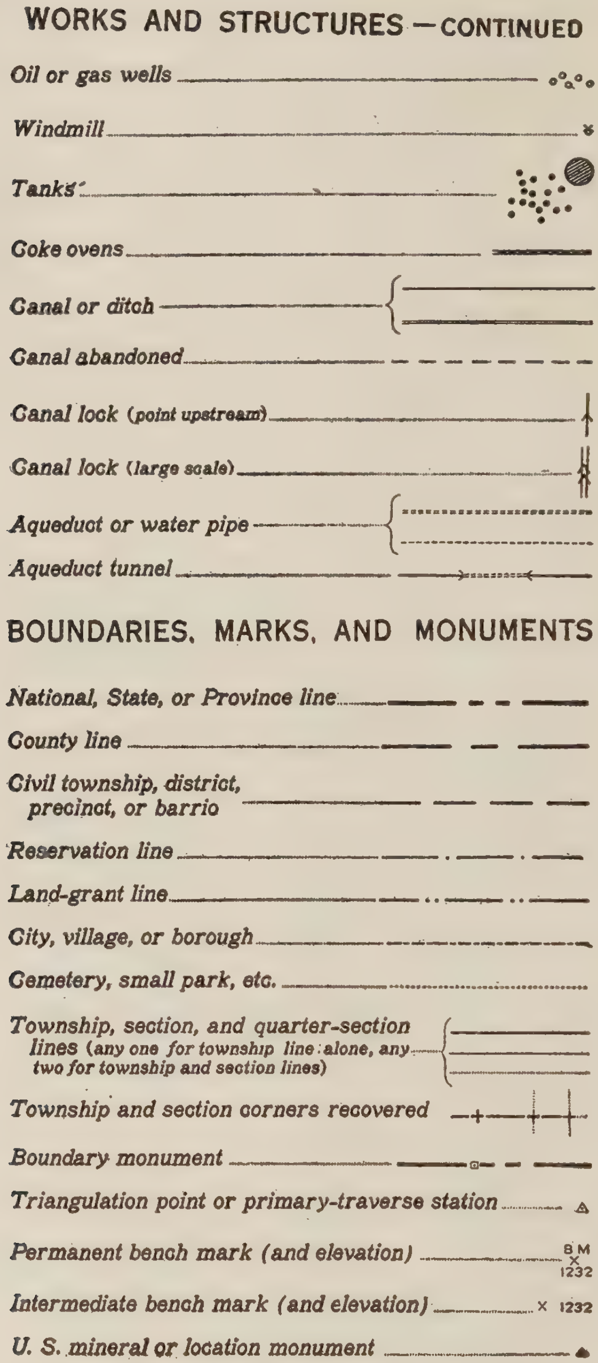

FIG. 29.—Standard symbols

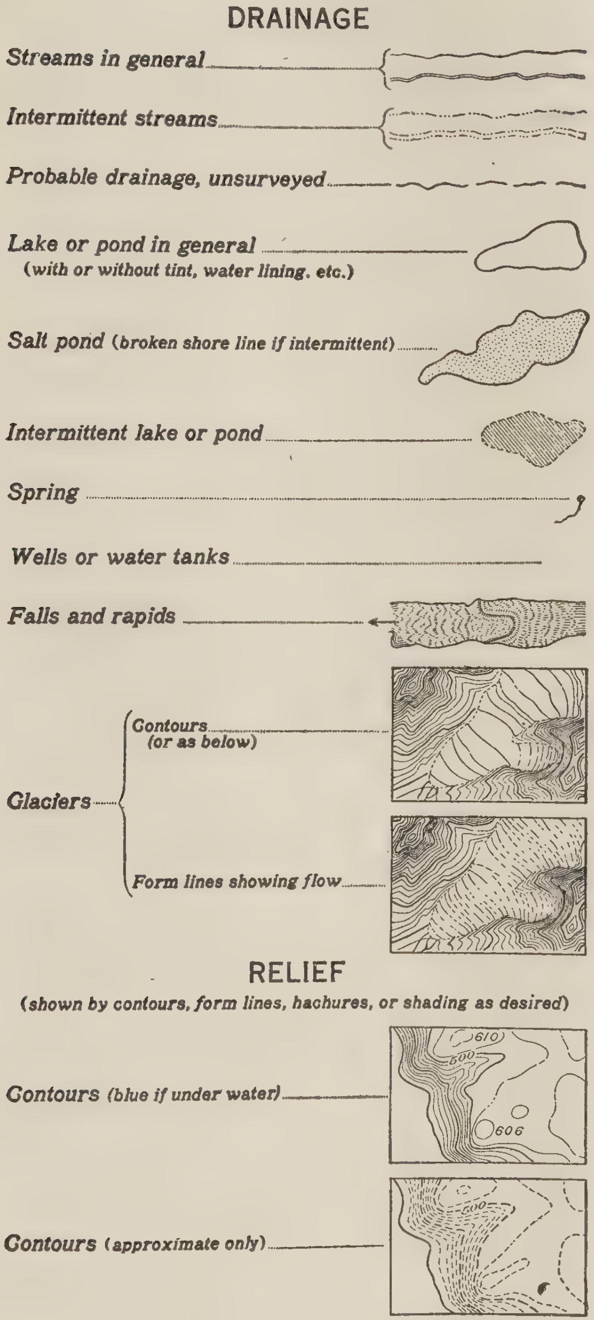

FIG. 30.—Standard symbols

RELIEF—CONTINUED

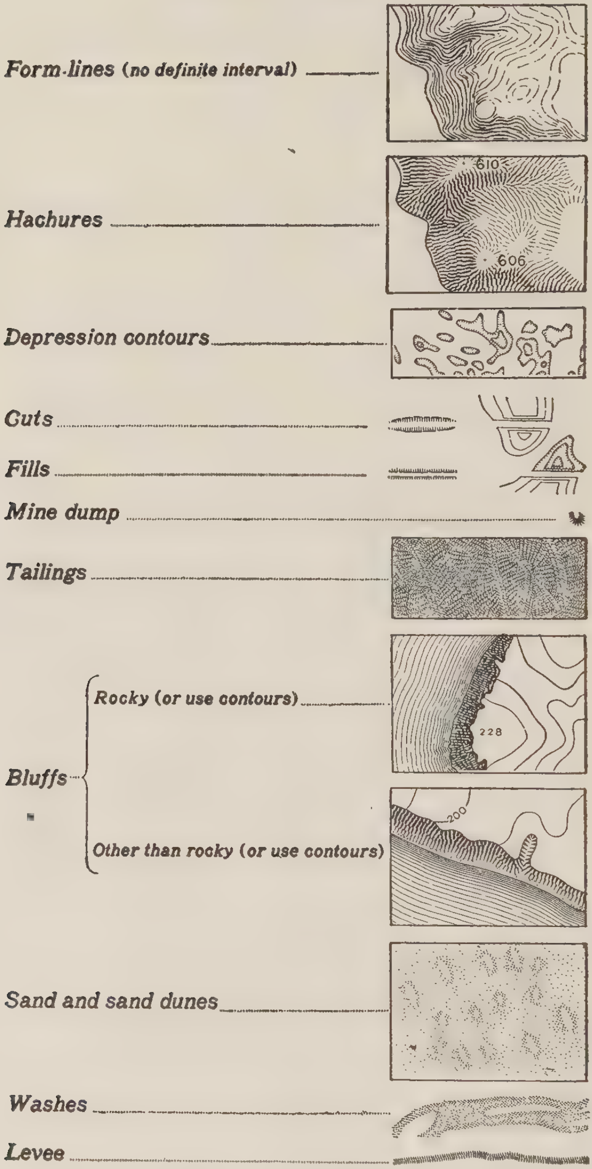

FIG. 31.—Standard symbols

LAND CLASSIFICATION

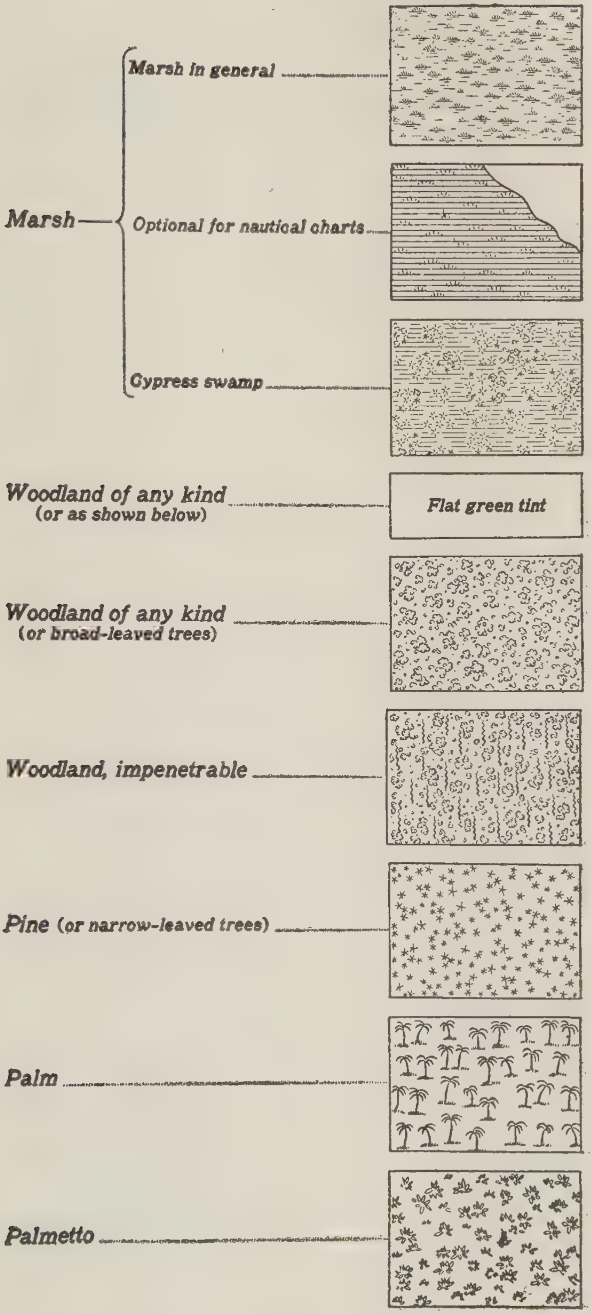

FIG. 32.—Standard symbols

LAND CLASSIFICATION

CONTINUED

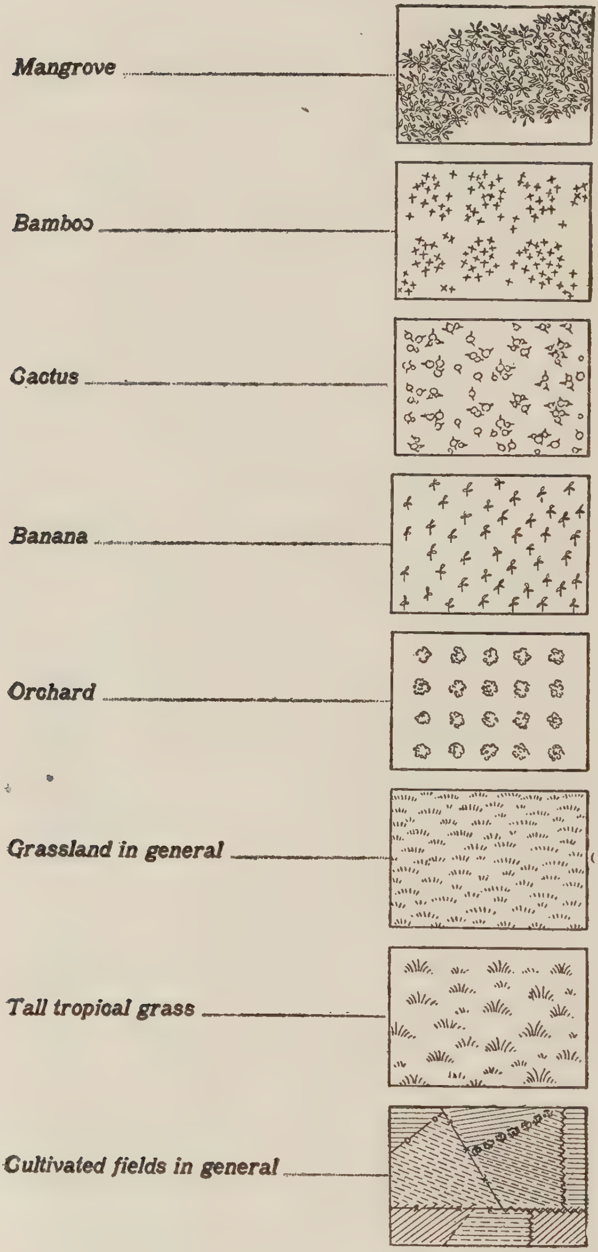

FIG. 33.—Standard symbols

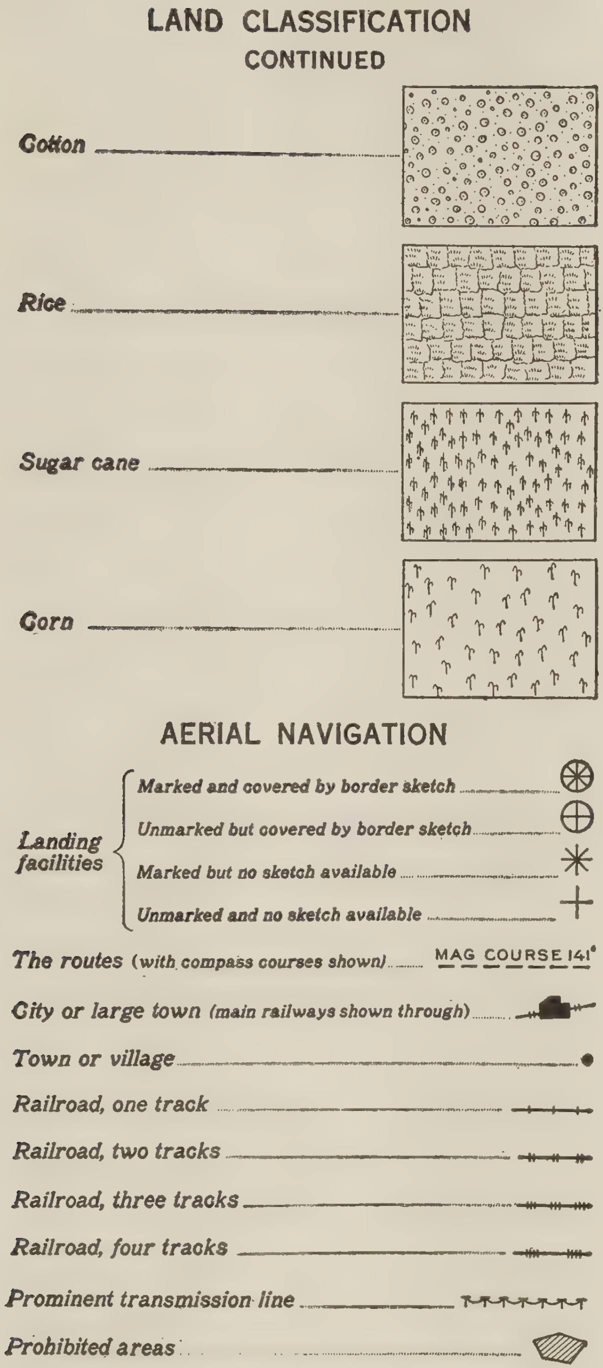

FIG. 34.—Standard symbols

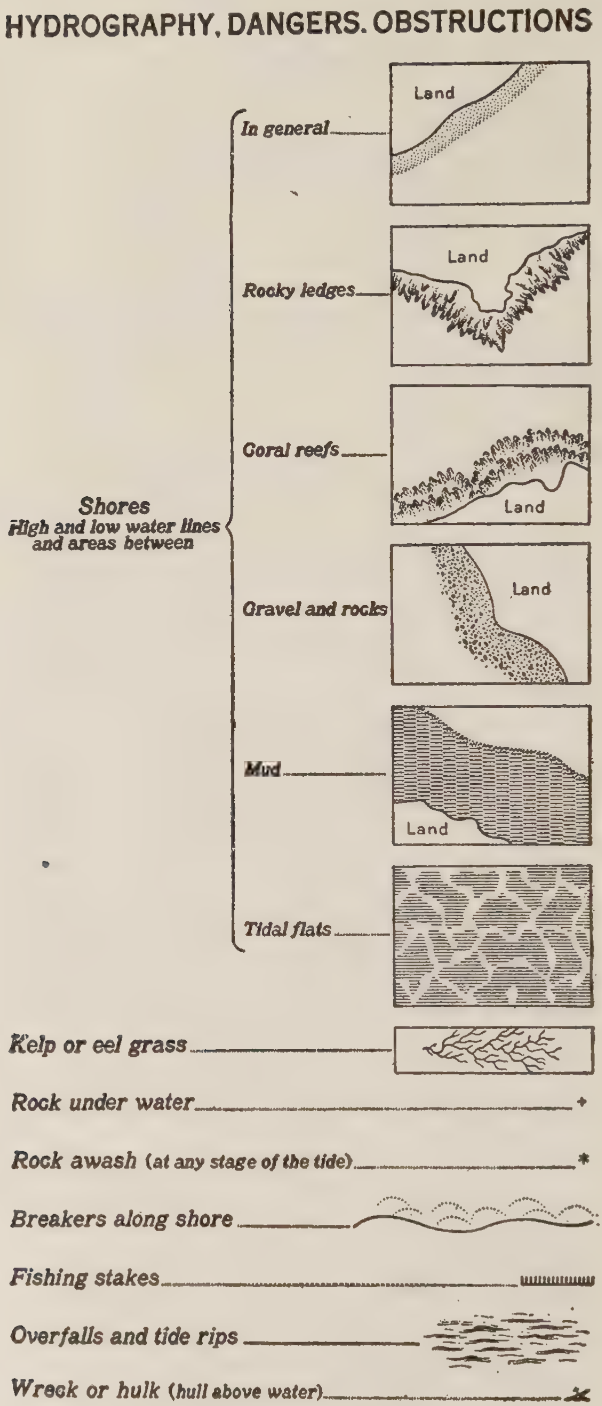

FIG. 35.—Standard symbols

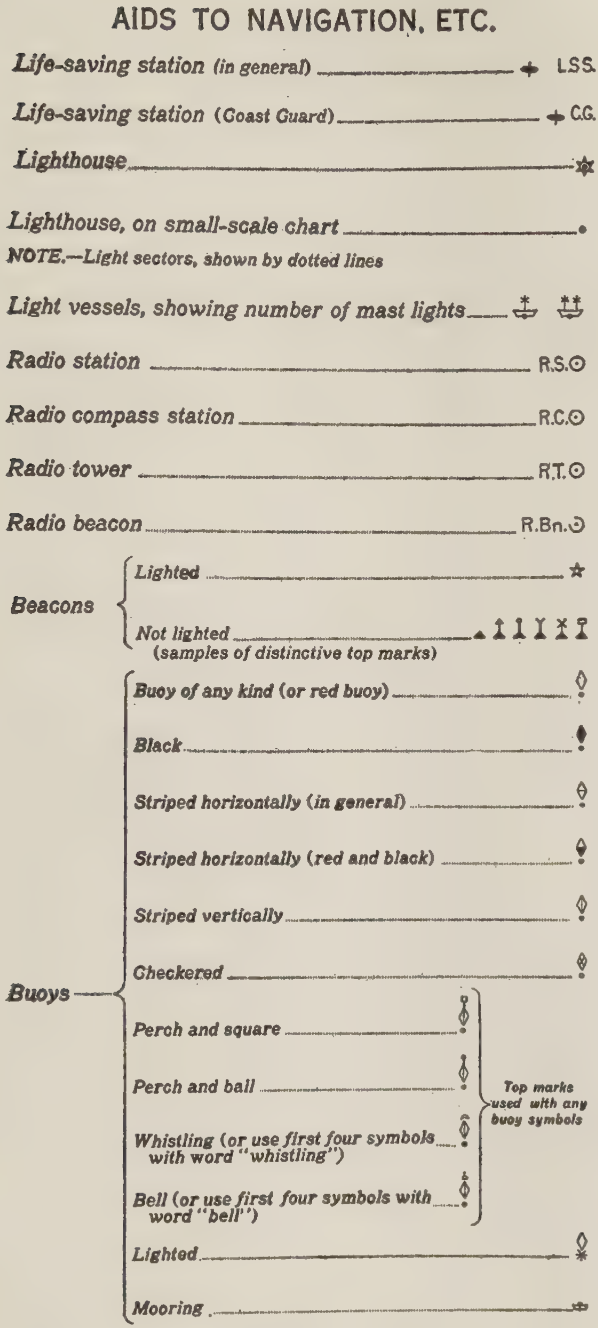

FIG. 36.—Standard symbols

ABCDEFGHIJKLMNOPQRSTUVWXYZ&

ABCDEFGHIJKLMNOPQRSTUVWXYZ&

abcdefghijklmnopqrstuvwxyz

abcdefghijklmnopqrstuvwxyz

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

FIG. 37.—Standard lettering for topographic sheets

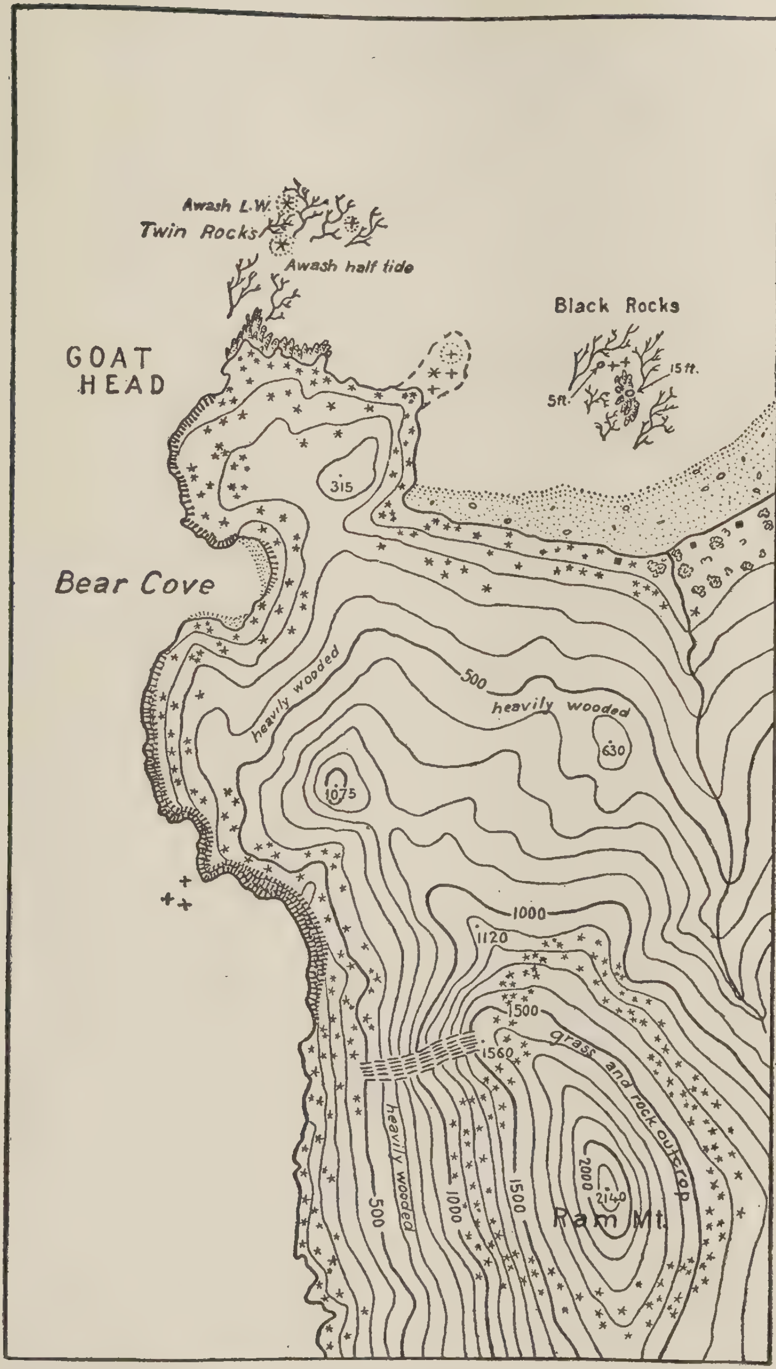

FIG. 38.—Section of topographic sheet showing heavily wooded headland; shores steep in places; offlying rocks surrounded by kelp; relief shown by form lines

FIG. 39.—Section of topographic sheet showing water front and adjacent streets of town

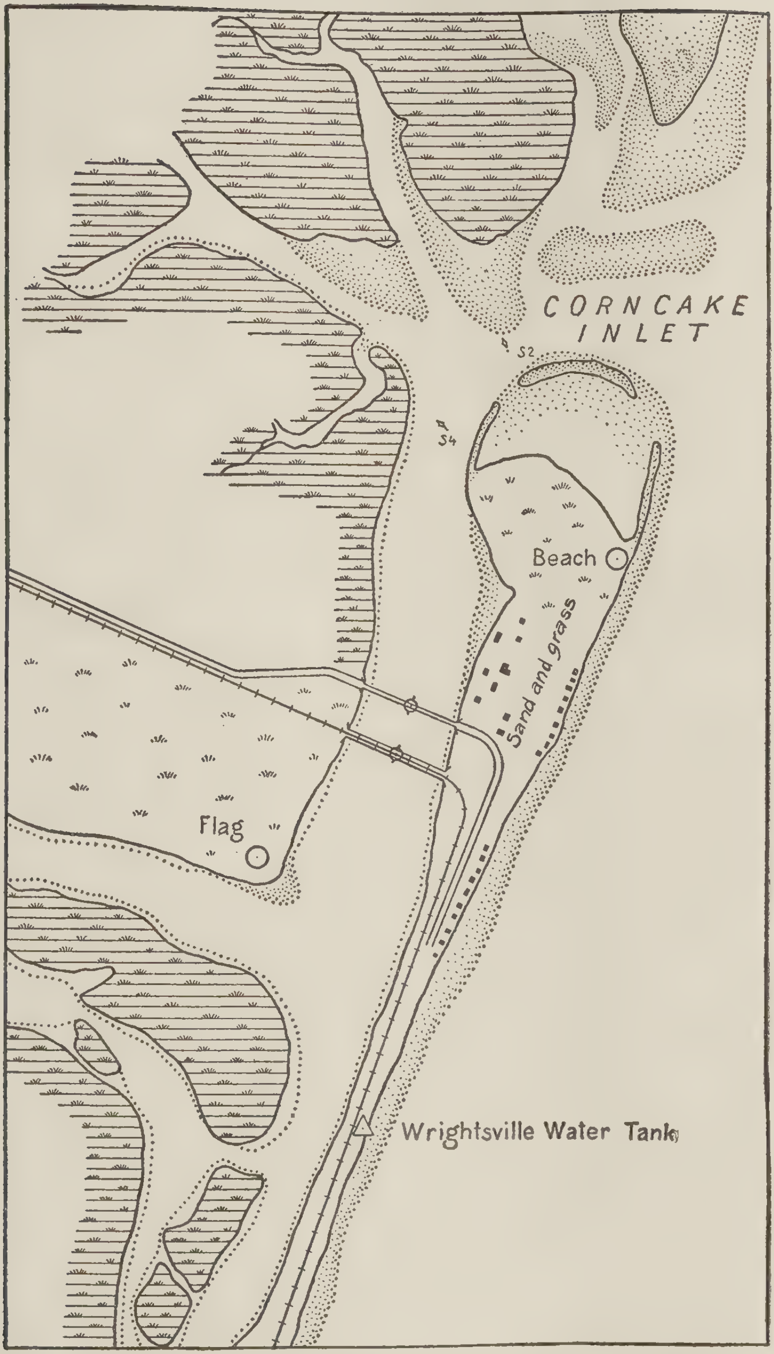

FIG. 40.—Section of topographic sheet showing inlet with low, marshy shores, separated from the ocean by a narrow sand beach. A highway and railroad extend over drawbridges across the inlet to a beach resort

INDEX

[Page numbers of part 1 of this manual, where the general requirements of the Coast and Geodetic Survey with respect to the various subjects will be found, are printed in italics]